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# Uncovering strata: an investigation into the graphic innovations of geologist Henry T. De la Beche

Renee M. Clary

*Louisiana State University and Agricultural and Mechanical College*

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**UNCOVERING STRATA: AN INVESTIGATION INTO THE  
GRAPHIC INNOVATIONS OF GEOLOGIST HENRY T. DE LA BECHE**

A Dissertation

Submitted to the Graduate Faculty of the  
Louisiana State University and  
Agricultural and Mechanical College  
in partial fulfillment of the  
requirements for the degree of  
Doctor of Philosophy

in

The Department of Curriculum and Instruction

by

Renee M. Clary

B.S., University of Southwestern Louisiana, 1983

M.S., University of Southwestern Louisiana, 1997

M.Ed., University of Southwestern Louisiana, 1998

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Photographs of archived documents held in the British Geological Survey library are reproduced with permission. I would like to thank Mr. Graham McKenna, Chief Librarian and Archivist, for his time and valuable assistance in this research investigation. Mr. McKenna also provided numerous articles on De la Beche that were difficult to access in the United States.

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## Abstract

An historical investigation into the types of illustrations in the Golden Age of Geology (1788-1840) revealed the nature and progression of graphic representation at the dawning of geology as a science. Exhaustive sampling of geology texts published in the period of focus proceeded until saturation was achieved. Qualitative analysis and evaluation of early illustrations were accomplished with Edward R. Tufte's theory of graphic design. Hypothesis testing around a correlation coefficient revealed significance at the 99% confidence level for relationships between publication year and number of included graphics, and publication year and the graphic density of texts. Henry T. De la Beche emerged as an important geologist who made numerous innovative graphic contributions in the Golden Age of Geology. De la Beche promoted *colliding theory graphics*, or the accurate portrayal of the earth's sections and scenes that would remain valuable for future generations of geologists. He was apparently the first geologist to utilize the small multiple format. De la Beche also designed and drew scientific caricatures that encapsulated the theoretical debates of the day, as well as the social, cultural, and historical influences on the emerging theories of geology. These scientific caricatures have emerged as instructional graphics with significant classroom potential for teaching the nature of science. De la Beche also drew the first portrayal of a scene from deep time, *Duria antiquior*, which became the first innovative classroom geology teaching graphic. Through his introduction and development of several important genres of visual explanation, De la Beche emerged as the *Father of Visual Geology Education*.

## Chapter 1: Introduction

In 2001, Simon Winchester published *The Map That Changed the World*. A commercial success, the book might have easily been entitled, *The Map and the Book Bringing Geology to the Masses*. Winchester discussed the life and geological contributions of William Smith, the son of a common blacksmith who worked as a surveyor in England during the turn of the 19th century. Although many others working in the field might have noticed the peculiarity before, it was William Smith who recognized the potential of fossil assemblages: Groups of fossils invariably succeed one another within sedimentary rock layers in a regular, predictable order. Smith's life-long ambition became the development of a *geological* map of England, a map that would show the strata of England based upon the fossil evidence. Although this would not be the first geologic map – Guettard had earlier realized that rock formations could be followed across the land and had published a geologic map of France in 1780 (Ford, 1993) – this would be the first geologic map based on fossil succession. In 1815, after many procrastinations and setbacks, William Smith's map was finally published. It was, according to Ford (1993), “a more beautiful work” than Cuvier's legendary fossil books (p. 140). The map should have immediately secured William Smith's standing as a prominent geologist. Unfortunately, social status also contributed to eminence in the early field of geology; great geological discoveries were insufficient to garner the respect of the notable geologists of the time. Smith's lamentation in 1816 was that the theory of geology was in the possession of one class of men, while the actual practice of geology was in the possession of another (Woodward, 1907).

Smith's contribution to geology was in recognizing the predictable nature of fossil assemblages, which is crucial in the geological discipline of stratigraphy. Simon



Winchester's (2001) contribution was in the promotion of William Smith, a geological figure under-recognized in his lifetime. The commercial success of *The Map That Changed the World* ensured that many within the general population were educated, not only to the cultural and political constraints in geology of the early 19th century, but also to the basic geological understanding of fossil succession and cartography. Winchester also presented Smith's crowning graphic achievement – the geological map of England and Wales with a part of Scotland – skillfully folded as the dust jacket of the book. Had Winchester also included instructions on how to *interpret* and *use* Smith's map effectively, geologic science literacy would have made even greater progress with *The Map That Changed the World*.

### Geology Instruction and the Importance of Graphics

William Smith's contribution, the first comprehensive geologic map of England, Wales, and part of Scotland, is important not only in its revolutionary decoding of geologic strata, but also because it is a *visual* representation of geologic strata. Geology, like biology, is a very visual science. Introductory geology and earth science textbooks are filled with maps, graphs, photographs, and diagrams. As geology students advance, they are further exposed to phase diagrams in geochemistry, graphic depictions of seismic data in subsurface geology, and diagrammatic cross sections showing force, pressure, and strain in geomorphology. The extended field experience requirement for undergraduate geology majors also confirms the visual aspect of the field; most undergraduate geology programs mandate several weeks of field camp during which students must apply what they have been taught during *visual* interpretation of "new" formations. In geology and earth science classroom lectures, graphics are interspersed via overhead transparencies, slide projections, and computer presentations. Although

geoscience teachers may not realize that this instructional approach of combining auditory and visual presentations is supported by psychological research, Paivio (1971, 1991) explored and promoted the role of both visual and verbal coding as effective in improving retention.

When used effectively, geology graphics have great educational potential. Photographs allow the viewer to explore geological information that is found at a far-away site, and multivariate graphs provide a wealth of data for the reader to access. In the Howe-Russell Geoscience Complex at Louisiana State University, there is a very large (approximately 30 feet wide by six feet high) graphic displayed in a side hall, immediately off the main entrance hall. The graphic, divided into two obvious parts, displays in its lower section seismic data procured in the Gulf of Mexico, from near offshore Louisiana to the end of the continental shelf. The upper section of the graphic reveals drilling block information along the seismic line.

The graphic can best be described as a “super graphic.” Its data are high in density and multivariate in nature. Various sources of data are combined in a large format to provide a powerful example of a multitude of information within a convenient and condensed presentation.

However, as impressive as it is, the Howe-Russell graphic still misses an opportunity to educate the non-geologist. The information and seismic “language” of the graphic is specific to the geology community, and the information is not interpreted for the lay viewer. There is no title for the graphic. Only one small description is available, and it does not include keys for the many symbols and color codes presented. Salt diapirs, rollover anticlines, and listric faults are briefly mentioned, but are never clarified. Unfortunately, as noted by Globus and Raible (1994) in their discussion of scientific

visualization, the absence of color keys and annotations is more likely to lead to an appreciation of graphic beauty, without concomitant scientific understanding.

In its current location, constraints of space and reflective lighting prohibit the viewer from simultaneously accessing all the Gulf of Mexico subsurface data in the Howe-Russell graphic in a “big picture” view. The viewer is also not able to fully comprehend the macro/micro aspects of the graphic design within the limited viewing space. The graphic is an example of geoscience education possibility, a possibility that is currently undermined and unrealized by lack of interpretation. Interactive displays, such as “light-up” geologic features, well logs, and micropaleontological data would add to the viewer’s understanding, as well as make the graphic more interesting. Interactive displays might also involve notations and aural explanations of various geological features and generation of data; this would apply the auditory-visual dual coding approach to learning (Paivio, 1971, 1991) about geology.

### Geological Graphic Success

Although it is obvious that geology graphics, by themselves, may not necessarily constitute excellent geoscience education, graphics do play a central role in the geologic education process, especially when they are actively incorporated into the geoscience classroom. The success of a graphic as a teaching tool depends on many variables, with the quality of the data being one of the most important factors. Edward R. Tufte, Professor Emeritus at Yale University, is the author, designer, and publisher of three books on graphic design (Tufte, 1990, 1997, 2001). Tufte noted that the best graphic designs are multivariate in nature, have a macro/micro or small multiple design, or contain layered information. “Chartjunk” – nonessential data ink – should be minimized on a graphic, while data ink should be maximized in its density per unit area. Tufte

(2001) believed that graphical excellence is “the well-designed presentation of interesting data – a matter of *substance*, of *statistics*, and of *design*” (p. 51). Well-designed graphics, whose correct usage and interpretation are taught to students, are practically invaluable in geology and earth science classrooms.

### Early Geological Graphics

Although graphics currently occupy a central role in geology, the history of the use of graphics in geology is seldom addressed. Whereas modern textbooks incorporate numerous diagrams, graphs, maps, and photographs, the role of these items in earlier texts has not been adequately discussed. The absence or presence of graphics in texts marking the beginning of modern geology – the proposal of theories and principles accepted in the science – and throughout the early years of geologic publications remained to be investigated until this study. Therefore, the task of graphic identification must, of necessity, begin with a delineation of what constitutes the early period of modern geology.

### The Beginning of Modern Geology

Modern geology is a relatively young science, although it does incorporate disciplines that have longer histories, as well as affinities with other sciences. Paleontology is claimed by both biology and geology as an area of focus, while chemists, as well as geologists, study mineralogy. Although maps are essential in the geologic sciences, these early graphics have their earlier roots in cartography, a discipline of geography. When textbooks claim an origin to modern geology, neither the birth of paleontology nor mineralogy nor geography is considered as a foundation for the new science. Instead, historians deem the theories of the earth’s processes as central to the study of geology, and it is in this vein that James Hutton is usually named as the father of

modern geology (McGeary, Plummer, & Carlson, 2001; Monroe & Wicander, 2001a, 2001b). Even in textbooks where no father of modern geology is attributed, Hutton is credited for the radical idea of uniformitarianism, which, at that time, upset conventional wisdom (Condie & Sloan, 1997; Hamblin & Christiansen, 2001; Plummer & McGeary, 1996). Uniformitarianism is also identified in textbooks as one of the primary fundamental principles of modern geology (Lutgens & Tarbuck, 2000, 2002).

Popular histories of geology credit the beginning of modern geology with James Hutton's proposal of uniformitarianism as an explanation for the processes that shaped the earth. Simply stated, Hutton's proposal was "the present is the key to the past." Therefore, in order to determine how the earth's present landscape had formed, scientists must investigate the processes currently operating – such as wind, running water, and ice – and apply them throughout earth's history. The idea that currently observed processes modifying the earth's landscape also operated in the past was not necessarily radical. What was new and debated, however, was the magnitude at which these processes operated in the past. Uniformitarianism argues that the geologic processes which operate today also operated in the past at the same *magnitude*, and at the same *rate*. This construct was antithetical to the views of the dominant geologists of the day, the catastrophists, who believed that cataclysms, processes unlike any that could be presently observed, were most responsible for the earth's current geomorphology. Catastrophists invoked the Bible as evidence; Noah's flood was often cited as the "mechanism" for catastrophic deposits (Buckland, 1824). Catastrophism had the further advantage of not having to confront a very ancient earth. If cataclysmic events operated in the past, they could wreak havoc on the earth's landscape in a limited amount of time. Many

prominent scientists in the early half of the 19th century were catastrophists, including Cuvier, Buckland, Sedgwick, and to a lesser extent, De la Beche.

The principle of uniformitarianism forced geologists to confront a very old earth. Hutton remarked, “The result, therefore, of our present enquiry is, that we find no vestige of a beginning, – no prospect of an end” (Hutton, 1788/1970b, p. 128). Hutton’s friend, John Playfair, also noted the enormity of time required for the interpretation of this new theory. It was Playfair, who on a field excursion with Hutton to Siccar Point, Scotland, gazed upon the angular unconformity and remarked he was looking into the “abyss of time.” The principle of uniformitarianism was an obvious contradiction to James Ussher’s biblical calculation that the earth was only a few thousand years old, having originated in 4004 B.C.E.

Hutton’s new theory initiating the development of modern geology was expanded from its original 1788 paper into a two-volume book in 1795, *Theory of the Earth with Proofs and Illustrations*. Not only did Hutton instigate a new theory for the operation of the earth’s processes, but he also promoted a different origin for granite. Whereas the established thinking of the day accepted the view proposed by Abraham Werner that all rocks were precipitated in a primeval ocean, Hutton argued more scientifically that granite formed from a molten state. As a result, Hutton’s theories invoked debate not only between the new uniformitarians and the resident catastrophists, but also between the new “Plutonists” or “Vulcanists” and the old “Neptunists” who followed the teachings of Werner. Wyllie (1999) believed it was the debate between the Volcanists and Neptunists, that “with its religious overtones, has become ensconced in textbooks as the classic debate that ushered geology in as a ‘real science’” (p. 37).

## Reception of the Huttonian Theories

Wyllie (1999) stated that Hutton's ideas were so opposed to the accepted Wernerian view that few scientists paid them any attention. Indeed, it was noted by Silliman (1829) that the Huttonian theory, in which "all rocks or strata have been either formed or consolidated by central subterranean fire, was warmly opposed; and much personal animosity and many adventitious circumstances were associated with the contest" (p. viii). It is important to note that Hutton's theories would have, perhaps, slipped into geological obscurity had it not been for the efforts of one of Hutton's good friends, John Playfair. Playfair believed Hutton's ideas were worthy of consideration, and promoted them after Hutton's death in *Illustrations of the Huttonian Theory of the Earth* (1802/1956). Most geology textbooks attributed the lack of success of Hutton's theories to his poor, cumbersome writing style (Monroe & Wicander, 2001a, 2001b; Tarbuck & Lutgens, 2000, 2002). Playfair (1803/1970), however, believed that several causes were responsible for the indifference:

The world was tired out with unsuccessful attempts to form geological theories, by men often but ill informed of the phenomena which they proposed to explain . . . Men who guided their inquiries by a principle so inconsistent with the limits of the human faculties, could never bring their speculations to a satisfactory conclusion . . . Truth, however, forces me to add, that other reasons certainly contributed not a little to prevent Dr. Hutton's theory from making a due impression on the world. It was proposed too briefly, and with too little detail of facts, for a system which involved so much that was new, and opposite to the opinions generally received. The descriptions which it contains of the phenomena of geology, suppose in the reader too great a knowledge of the things described. (p. 165)

Playfair's comments are even more interesting, and perhaps cryptic, when it is revealed that Hutton also not only intended but also wrote a third volume to his 1795 *Theory of the Earth with Proofs and Illustrations*. Upon his death, the manuscript fell into the hands of

John Playfair, who failed to publish it. When the manuscript was located and published almost 100 years later (Hutton, 1899/1997), the editor, Sir Archibald Geikie, noted that some serious reason must have kept Playfair from publishing Hutton's third volume, since it was acknowledged to be necessary for completion of the theory. Bailey (1967) believed that the reception of Hutton's first two volumes in 1795 was such a disappointment to Playfair that he undertook a clarification of Hutton's views rather than risk the publication of the third volume. Craig (1978) concurred that Playfair sought to clarify Hutton's first two volumes instead of readying a third volume for publication, and in so doing, Playfair borrowed from Hutton's remaining manuscript.

Ironically, although Playfair attempted to expand and explain Hutton's theories, modern geology textbooks rarely mention his efforts. Instead, Charles Lyell is given credit for advancing the basic principles and theories of modern geology (Lutgens & Tarbuck, 2000, 2002; McGeary, Plummer, & Carlson, 2001; Monroe & Wicander, 2001a, 2001b). Lyell wrote the three-volume *Principles of Geology* (1830-1833/1991). Indeed, it was not until William Whewall's review of Lyell's text appeared that the construct proposed by Hutton and adopted by Lyell was designated as "uniformitarianism" (Gould, 1987). Lyell is often credited for doing more than anyone else to establish geology as a scientific discipline. It is said that he gave the science credibility among both geologists and the literate public (Blundell & Scott, 1998).

Interestingly, Rudwick (1998) reported that Lyell, like most of his contemporaries, did not take the Huttonian theories from the original works of Hutton, but from the illustrated Playfair version! Even though Lyell followed both Hutton and Playfair in advocating the concept of uniformitarianism, the intervening time had not witnessed massive support for the idea. In particular, geologists still resisted the notion



that processes in the past had never acted in differing magnitude from those currently witnessed. By supporting uniformitarianism, Lyell diverged in his stance from most geologists at the time, and therefore, had a “major task of persuasion ahead of him, if he was to convince other geologists – let alone the general educated public – that everything in the geological record could be adequately explained in these terms” (Rudwick, 1998, p. 7). Rudwick further noted that Lyell’s training as a barrister was an asset, since *Principles of Geology* read like a “barrister’s brief” throughout the three-volume set. Although the task of promoting uniformitarianism was formidable, Lyell obviously rose to the occasion. He is credited with doing more than any other scientist of his time to advance geological progress, both as an historian of geology and as an original observer (Woodward, 1907).

### Age of Focus

Obviously, an investigation into the early graphics contained in geology texts must begin with the first proposal of the concept of uniformitarianism by James Hutton (1788/1970b). Uniformitarianism is the process acknowledged for the formation of most of the earth’s features we observe today. The National Academy of Sciences (1995) specified the Earth’s history, as well as the origin and evolution of the earth system, as content standards in earth and space education. But, as has been previously noted, Hutton’s ideas were not immediately embraced. The eventual acceptance of uniformitarianism and the igneous origin of granite occurred only after rigorous promotion of Hutton’s ideas by other proponents and through other vehicles. The early period of modern geology must also encompass other writings that promoted the modern principles of geology. Texts by Playfair (1802/1956) and Lyell (1830-1833/1991) were key factors in the history of the foundational concepts of modern geology. Therefore, the

time period of focus for early geological graphics is defined here as extending from the first proposal of Hutton's ideas, through the Golden Age of Geology. Sollas (1905) first identified the Golden Age of Geology as the time during which William Buckland was active, along with other distinguished geologists including Charles Lyell, Adam Sedgwick, Roderick Murchison, and Henry De la Beche. Woodward (1911) adopted the term, and further delineated a Grand Masters period in geology, extending from 1820 through 1840. It is in this time frame – 1788 through 1840 – that the current investigation of graphics in early geology texts was conducted.

### Early Figures in Geology

An overview of the history of geology and the geologic texts from the period 1788 through 1840 revealed several important scientists who contributed to the early modern field of geology. How visual were the early geologic publications of these scientists? Were graphics used in these publications, and if so, what roles did the graphics play? Examination of early scientists' publications for the presence or absence of graphics, as well as the type of graphics used, exposed a progression of early geology graphic application.

A pilot study that investigated the role of graphics incorporated in early modern geology texts was conducted in the fall 2001 (Appendix A). Since James Hutton's ideas are now considered to be the foundation for modern geology, Hutton's texts were a critical starting point for the pilot study. Initially it was believed that John Playfair, author of *Illustrations of the Huttonian Theory of the Earth*, had successfully promoted Hutton's concepts through the use of graphics because of the word "illustrations" in the book title. This text was also considered crucial evidence in the succession of early geology graphics. Charles Lyell's texts were likewise considered important in the

examination of early illustrations, since it was through Lyell that the Huttonian ideas and theories were successfully promoted. The pilot study initially focused, therefore, on the texts of Hutton, Playfair, and Lyell.

However, it was soon discovered that Playfair did not incorporate graphics into his text, and that his “illustrations” were metaphorical and verbal, not graphic. Consequently, the pilot study became more inclusive and the research shifted to the investigation of graphics within all geology texts that were published between 1788 and 1840, and which could be acquired through Louisiana State University libraries and interlibrary loan services. These early texts were identified through histories of geology (Geikie, 1905; Woodward, 1907, 1911), references to other books published as facsimile versions in a history of geology series (Conybeare & Phillips, 1822/1978), catalog searches, and Internet searches.

Several early geology texts were identified, acquired, and analyzed. In addition to James Hutton and John Playfair’s early geology texts, geology books by William Buckland, Alexander Humboldt, Robert Bakewell, and Conybeare and Phillips surfaced. Several paleontological texts – by such authors as Parkinson and Cuvier – as well as mineralogical texts – by Cleaveland, Phillips, and Thomson – were uncovered during the pilot investigation as well. Also emerging as a contemporary of Charles Lyell during the age of focus (1788-1840) was Henry T. De la Beche, a prolific geology writer and illustrator. The authors of the early modern geologic texts are depicted in Figure 1, and the use of graphics within their texts is discussed in the following sections.

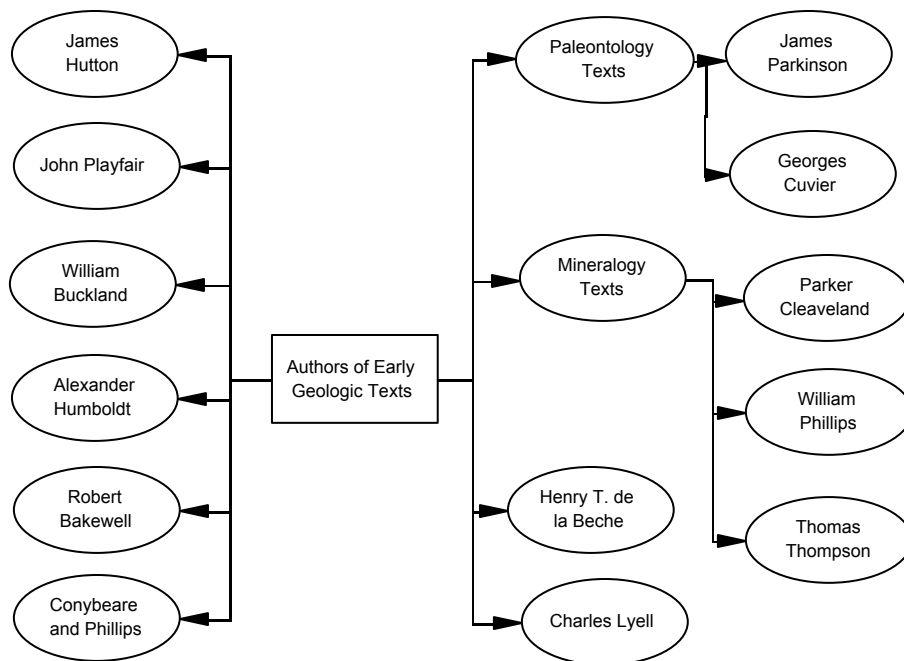


Figure 1: The authors of important early geologic texts that emerged in the pilot study (Appendix A).

## James Hutton

The first unanimously recognized publication of James Hutton was the 1788 paper, *Theory of the Earth*, which was originally read in 1785 to members of the Royal Society of Edinburgh (Hutton, 1788/1970b). However, an earlier abstract of a similar work surfaced in 1947, during the commemoration of the 150th anniversary of Hutton's death. This was, according to Bailey (1967), a strange coincidence. V. A. Eyles (1970) examined the abstract, officially titled *Abstract of a Dissertation Read in the Royal Society of Edinburgh, upon the Seventh of March, and Fourth of April, M,DCC,-LXXXV, Concerning the System of the Earth, Its Duration, and Stability*. Eyles noted that the *Abstract* contained several essential conclusions embodied in Hutton's later 1788 publication, and further stated that evidence showed the *Abstract* reached France, appeared in a scientific periodical, and was attributed to Hutton. Bailey (1967), however, disagreed with Eyles. He thought that the writing was distinctly different from Hutton's

for two reasons: The appeal for a design in nature was notably much shortened from the 1788 paper, and there was no mention of the igneous origin of granite. Bailey further opposed Eyles' conclusion because segments within the *Abstract* were essentially the same as segments within Playfair's 1802 *Illustrations of the Huttonian Theory of the Earth*. Bailey (1967) concluded, "The geology is the geology of Hutton, but the voice is the voice of Playfair" (p. 31). Although there now appears to be generally acceptance among the historians of geology that the 1785 *Abstract* is an earlier publication of Hutton, the fact remains that there are no graphics within the text (Hutton, 1785/1970a). The first graphic appearance in Hutton's principles of modern geology unquestionably occurred in the 1788 paper, *Theory of the Earth*.

Hutton incorporated only two plates of figures in *Theory of the Earth* (1788/1970b). These were placed as separate page insertions at the end of the text. There are no titles on either of the two plates, and only numbers identify individual figures. Within the text, the reader is referred to Plate I during a discussion of septarian nodules, although none of the four individual figures are referenced (Hutton, 1788/1970, p. 70). A reduced facsimile version of Plate II is shown in Figure 2. It depicts a total of 10 figures; figures 1 through 3 are individually referenced and discussed within the text as depictions of a type of porphyritic granite, with homogeneous feldspar crystallized groundmass (smaller background crystals), and transparent siliceous inclusions (larger crystals within the groundmass). Hutton also discussed the reversed case in which feldspar is included in the quartz, and these cases are referenced as figures 5 through 10. There are no individual graphics included within the 1788 text.

James Hutton expanded his use of graphic illustrations in his two-volume 1795 book, *Theory of the Earth with Proofs and Illustrations*. Volume I included four foldout

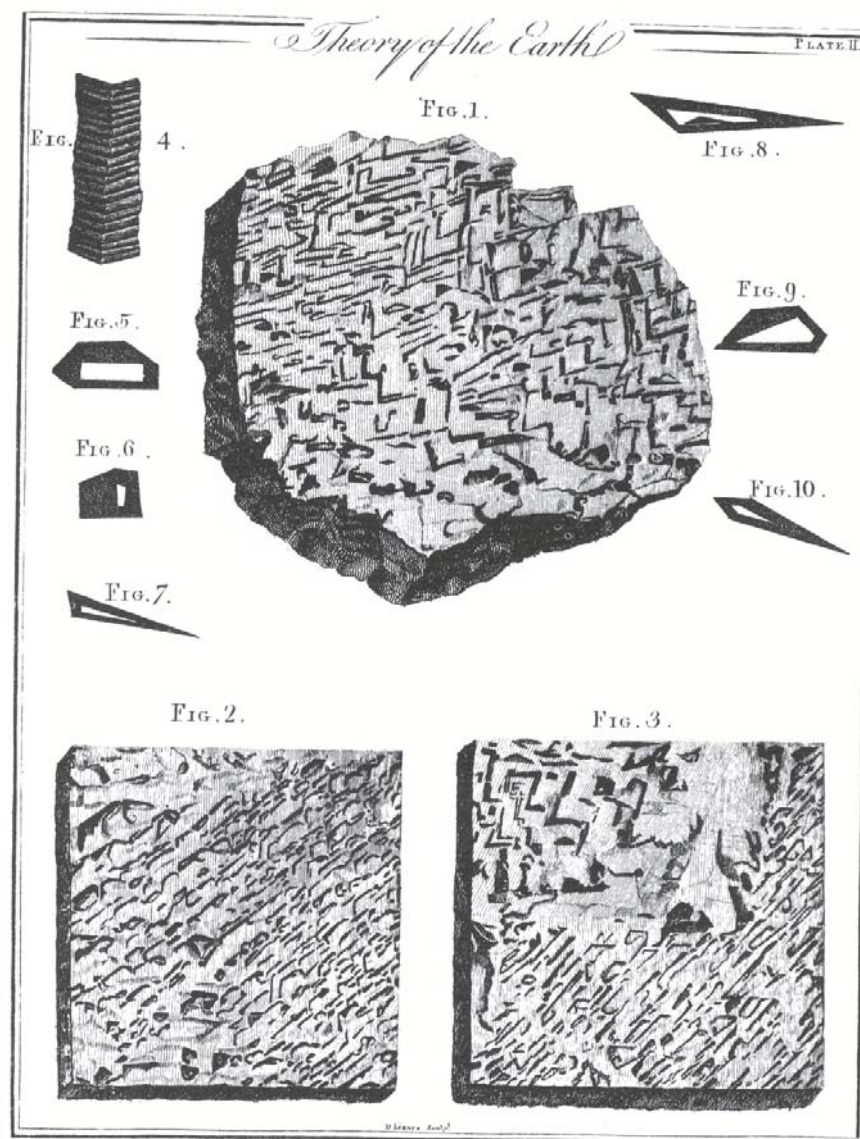


Figure 2: Plate II from James Hutton's 1788 paper, *Theory of the Earth*. All 10 figures are referenced and discussed in the text as depictions of granite. (From Hutton, 1788/1970b)

plates, two of which are exactly the same as Plates I and II in the 1788 paper. Hutton also used the exact same sentences to introduce the two plates as he used in 1788. However, there exists a case of “graphic misidentification,” having resulted from either Hutton’s or the printer’s carelessness in handling the graphics. Volume I referred to Plate I as the “most elegant septarium” in circular or horizontal section, but in the 1795 *Theory of the Earth with Proofs and Illustrations*, the position of Plate I is occupied by the 1788

Plate II (Hutton, 1795/1959, p. 82)! Likewise, the same text also referred the reader to the 10 figures depicted in Plate II, but this plate has been transposed with Plate I and occupies the first position among the plates. The absence of titles, and even identifying plate numbers, also adds to the reader's confusion, and makes the graphics more decorative than functional.

Plates III and IV were new to the 1795 book. Plate III is a cross sectional depiction along the River Jed in Scotland, drawn by Mr. Clerk. The plate is identified in the text as

vertical strata or schistus mountains . . . in general the hard and solid parts of those indurated strata, worn and rounded by attrition; particularly sand or marl-stone consolidated and veined with quartz, and many fragments of quartz, all rounded by attrition” (Hutton, 1795/1959, p. 437).

Although the plate is identified as “Vol. I. Plate III,” the reader is referred in the text by asterisk to “plate 3d.” Consistency in graphic design and referral does not seem to be a trait of James Hutton's 1795 text. A reduced facsimile of Plate III is presented in Figure 3. It is interesting that the diagram not only incorporated a cross sectional view of the strata, but has artistic details added in as well.

Plate IV in Hutton's 1795 volume I was described as a drawing by Sir James Hall of a section of a cliff at Lumesden burn, showing anticlinal and synclinal deformation. Hutton did not refer to the illustration in the text as Plate IV, but as “Fig. 4.” (Hutton, 1795/1959, p. 460). Plate IV is much less detailed than Plate III.

In Volume II of *Theory of the Earth with Proofs and Illustrations*, Hutton inserted two foldout plates. However, unlike Volume I, and the 1788 paper, one of these plates was added at the beginning of the volume. These plates are very stylized drawings of a mountainous region, and both do have titles. However, the titles are in French. The

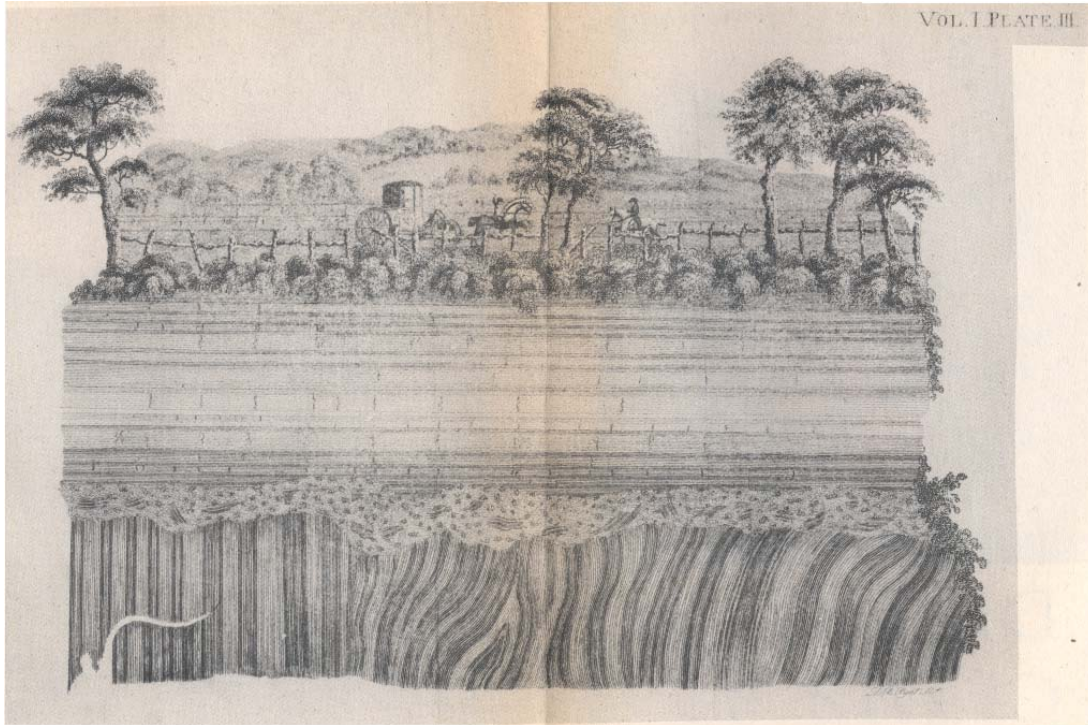


Figure 3: Plate III from James Hutton's 1795 *Theory of the Earth with Proofs and Illustrations*, showing a cross sectional view along the River Jed, Scotland. (From Hutton, 1795/1959)

second plate in Volume II also has alphabet labels at the top of the drawing. On page 297, Hutton (1795/1959) identified the source of the drawings: "M. de Saussure . . . has given us two views, the one in profile, the other in face, of the Mont-Blanc." Within the discussion of these two plates, Hutton again fell prey to misidentification. He specifically referred to the plates as "plate V" and "plate VI," although the first plate in Volume II is labeled "Vol. II Plate I," while the second plate is labeled "Vol. II PL." Additionally, Hutton further confused the reader by referring to alphabetic labeling in both plates V and VI. Even if the reader makes the transition that Plate V is the first Plate in volume II, there is no alphabetic labeling present.

Hutton's intended Volume III was not published until 1899, over 100 years after his death. As the editor of the manuscript, Archibald Geikie (1899/1997) noted that a cause for the delay in publication may have been that the illustrations for the text were



missing. Geikie proceeded to add his own illustrations to Hutton's text, helpfully incorporating them *within* the text instead of as plates at the beginning or end of the volume. Although the lost drawings have since been relocated, they have not been specifically identified as to their possible intended inclusion within Volume III of *Theory of the Earth with Proofs and Illustrations* (Craig, 1978). Craig (1978) observed, however, that the "drawings reveal that Hutton and his friends, especially John Clerk of Eldin, had an even greater understanding of the structure and evolution of the Earth than had hitherto been suspected" (preface).

### **John Playfair**

The title of Playfair's 1802 book explaining James Hutton's theory was the impetus for a pilot study conducted in the fall, 2001 (Appendix A). However, although Playfair named his text *Illustrations of the Huttonian Theory of the Earth*, he included no graphics. Playfair's use of the word "illustrations" was meant as a synonym for "explanations" or "examples." Playfair was by no means unusual in his complete absence of geologic graphics within a text: De Luc (1831), Moore (1834), Reboul (1833), and von Buch (1820) included no illustrations in their texts, and Boubée (1833), Greenough (1819/1978) and Reboul (1835) included only solitary graphics.

### **William Buckland**

Buckland's 1824 *Reliquiae Diluvinae, Or Observation on the Organic Remains Contained in Caves, Fissures, and Diluvial Gravel, and on Other Geological Phenomena, Attesting to the Action of an Universal Deluge* incorporated several types of graphics, including fossil sketches, maps, and cross sectional diagrams. The illustrations were offered in 27 plates that were presented at the end of the text, while descriptions of the plates were detailed in pages 259 through 279, before the plates. Many of the plates

included multiple figures, and three of the map plates are colored. Buckland was a catastrophist, and he described ancient deposits as diluvium, having been deposited by an ancient flood or tsunami. Rudwick (1998) noted that Buckland was Lyell's mentor, and reported that it was Buckland who sponsored Lyell for membership in the young Geological Society of London. Woodward (1907) considered Buckland one of the most active geologists of the time. Buckland also believed in the power of illustration and visual aids; he noted that his Oxford class was better "by way of a syllabus," and he asked fellow geologist Henry T. De la Beche for visual aids to use in his classroom (McCartney, 1977, p. 44). Buckland also urged De la Beche to draw several reconstructed scenes from the ancient world.

### **Alexander von Humboldt**

Humboldt's work belonged not only to geology, but to climatology, and therefore geography as well (Rudwick, 1998). Humboldt's geological contributions are well-cited, however (Cuvier, 1825a; De la Beche, 1824a; Woodward, 1911). Bailey (1967) described Humboldt as one of Werner's most distinguished pupils. Humboldt's 1832 book describing Asia included only two foldout plates, but they are of great graphic interest. The first plate, a polar projection with isotherms, was far more detailed, multivariate, and mathematical than any other observed geological graphics of this time. It is presented in Figure 4. The second plate was a map of Asia. Humboldt's later work in 1837 was in collaboration with Rose and Ehrenberg, and included four graphics in the text, with 10 plates inserted at the end of the text. Two plates were maps, while the rest of the plates showed crystallographic forms. The isographs were Humboldt's greatest contribution to the science of geology. Hankins (1999) reported that the most important "iso-lines" Humboldt introduced were isotherms – lines of equal temperature – that made

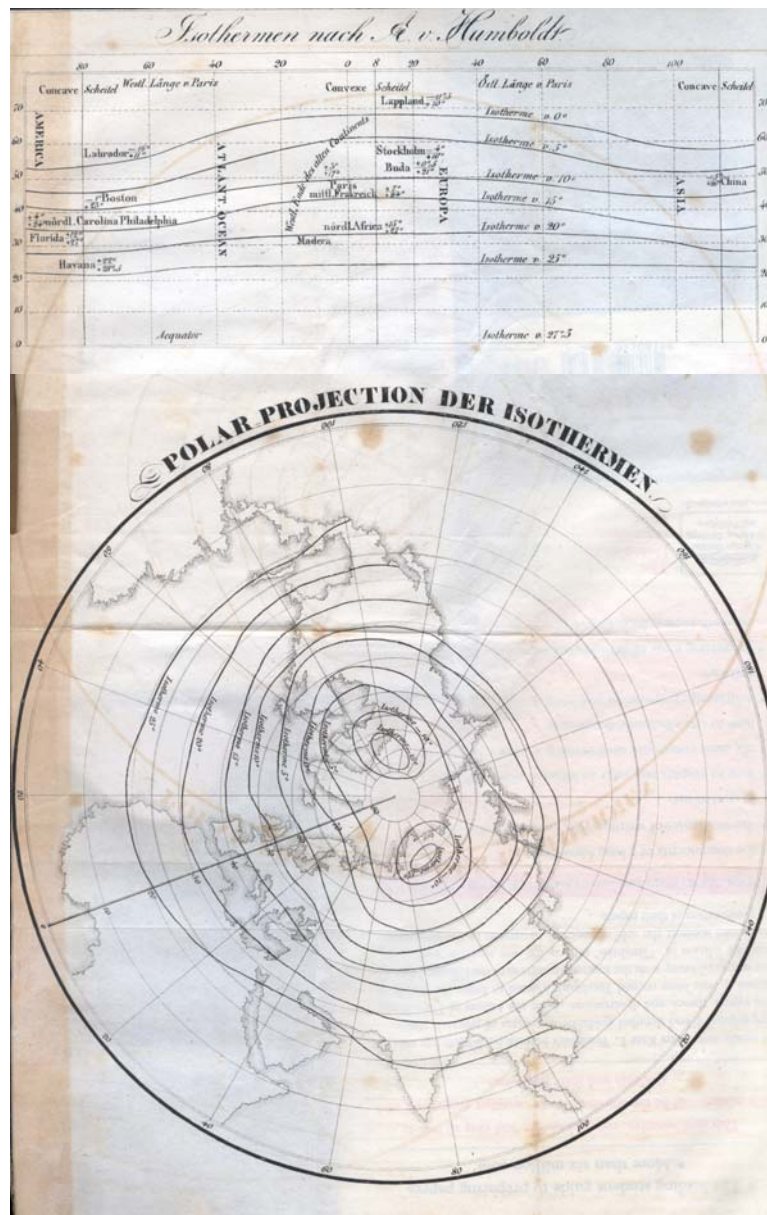


Figure 4: Composite graphic of Humboldt's isotherms across the polar region. (From Humboldt, 1832)

a first appearance in 1817. William Playfair, nephew of John Playfair and developer of modern statistical graphics, influenced Humboldt in this development of a thematic map – a map overlaid with a graph (Hankins, 1999). For Humboldt, this graphic was a vehicle that allowed the display of regularities within chaotic measurements, so that “a true physics of the earth” could be created (Hankins, 1999).

## **Robert Bakewell**

Although a prominent geologist, Bakewell was not a member of the Geological Society of London (Woodward, 1907). However, it was probably from Bakewell's introductory geology text that Lyell was introduced to the Huttonian theory of the old earth (Rudwick, 1998). Woodward (1907) identified this text, *An Introduction to Geology: Comprising the Elements of the Science in Its Present Advanced State, and All the Recent Discoveries; with an Outline of the Geology of England and Wales*, as “undoubtedly the best of the early text-books” (p. 84). A third edition of the introductory text (Bakewell, 1829) revealed seven pages of plates, incorporated into the text after the plate descriptions, but before the beginning of the text. There were no individual graphics incorporated into the text where needed. Several plates are foldouts, and a few are colored. The plates represented cross sections and map views. Plate 3 from this book is shown as Figure 5.

## **William Conybeare and William Phillips**

Geikie (1905) noted that Conybeare and Phillips' (1822) treatise summarized the formations and rocks of England “in so clear and methodical a manner as to give a powerful impulse to the cultivation of geology in England” (p. 399). In the Conybeare and Phillips text, illustrations were directly incorporated and described within the text. This is different from the presentation of most geologic graphics prior to the 1830s; formerly, most cross sectional views and maps were presented as figures in plates either preceding the text or following it. There were 23 graphics included within their text, and two foldouts at the end of the text – a map and cross sections. The first seven graphics were included in the introduction. The first four of these illustrations are general in nature, and show basic principles of strata. The remaining graphics, however, are

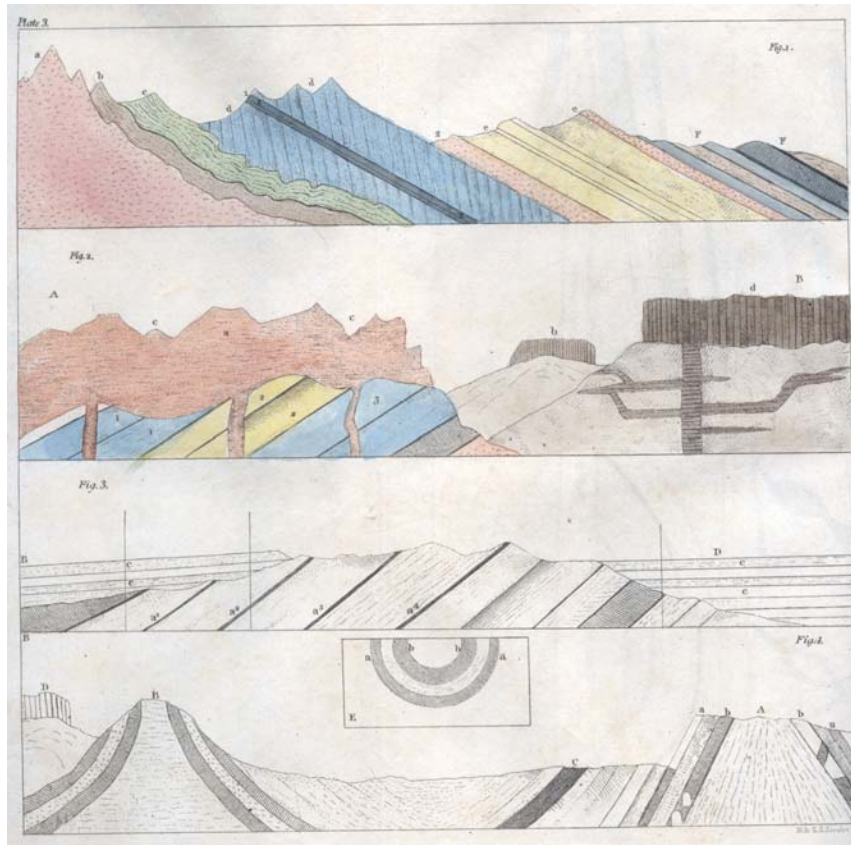


Figure 5: Cross sectional views depicting conformable strata, unconformable massive rocks, unconformable strata, and a stylized section of strata near Dudley. (From Bakewell, 1829)

illustrations of specific geologic examples observed by the authors. The 22nd graphic is unusual and innovative, in that a key is included below the illustration. A photograph of the graphic is presented in Figure 6.

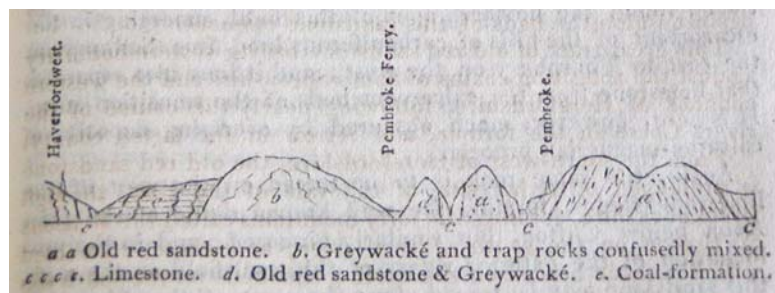


Figure 6: A cross sectional view of Pembroke, with direct and alphabetic labels within the diagram, and a key beneath the diagram. It is placed directly in the text. (From Conybeare & Phillips, 1822)

## Paleontological Graphics

Early paleontological textbooks are unusual in that they cannot be claimed as belonging solely to the field of geology. Biology also claims paleontology as a field of study. The paleontological graphics of the period under study, 1788-1840, are remarkably well-developed. Several books have illustrations of fossils; a few of the more famous authors are discussed in the next pages.

**James Parkinson.** Parkinson's texts (1804, 1808, 1811) are beautifully illustrated with hand-colored graphics. The first volume (1804) discussed the vegetable kingdom, and included nine plates inserted after the text. Unlike the other two volumes, the plates were described within the text, and no separate plate description section was included. The second volume (1808) contained 19 plates of zoophytes, while the third and final volume (1811) incorporated 23 plates of fossil mollusks, echinoderms, amphibians, and mammals. Parkinson's use of color was not always for aesthetic value alone. He noted,

It is proper to remark, that such only of the engravings of the present volume [volume 2], as are not coloured, have been taken from other works: and that all those, which are coloured, have been copied, for this work, from the specimens themselves. (Parkinson, 1808, p. xiv)

A representative sample from the first volume, illustrating beautifully colored remains of plants, is shown in Figure 7.

Parkinson (1822) also compiled a later book on fossils, *Outlines of Oryctology. An Introduction to the Study of Fossil Organic Remains; Especially of Those Found in the British Strata; Intended to Aid the Student in His Enquiries Respecting the Nature of Fossils, and Their Connection with the Formation of the Earth*. The text, intended to be

the fossil companion to Conybeare and Phillips (1822), included 10 plates, none of which were colored.



Figure 7: Fossil remains of plants. (From Parkinson, 1804, Plate V)

**Georges Cuvier.** Georges Cuvier, known for his brilliant studies in comparative anatomy, is also considered the father of paleontology (Ford, 1993), or more precisely, the father of vertebrate paleontology (Woodward, 1911). A strict catastrophist, Cuvier joined efforts with Brongniart to determine the geological history of the Paris Basin from the formations of the area and the fossils contained in the strata (Rudwick, 1998). Similar to most published works of the early 1800s, Cuvier and Brongniart's (1822/1969) publication included plates inserted at the end of the text, and did not incorporate



graphics directly in the text. The plates were, however, referenced in the text. An explanation of the figures also begins on page 373 and continues through page 402. There are nine plates with fossil depictions, a foldout colored map, and two “plates” with cross sections and maps. These two cross sectional “plates” are divided into four separate sub-plates, each depicting between three and five figures. One sub-plate, Plate 1a, is a foldout of vertical sections. Cuvier’s 1822 work (Volume II, second part, *Recherches sur les ossemens Fossiles, où l’on Rétablit les Caractères de Plusieurs Animaux Don’t les Révolutions du Globe ont Détruit les Espèces*) reproduced these illustrations. Other than the Cuvier and Brongniart (1822/1969) book and subsequent reprinting in the 1822 volume, Cuvier’s books included only graphics of fossils. However, it is the original 1811 version of the Cuvier and Brongniart text that is credited for the later beginning of modern geology in France (Woodward, 1907).

Cuvier’s (1831) translated book contained 10 engravings of fossils; like many later works of the 1830s, these are interspersed and described throughout the text. However, by the time the engravings were included in Cuvier’s 1831 text, they were already well-seasoned. Figures 7 through 10, depicting an ibis, made an appearance as early as 1812 as the only included illustrations in *Recherches sur les Ossements Fossils de Quadrupèdes* (Cuvier, 1812/1992). All 10 figures in the 1831 text were also identical to those included in the plates in the third edition of Volume I, *Recherches sur les ossemens Fossiles, où l’on Rétablit les Caractères de Plusieurs Animaux Don’t les Révolutions du Globe ont Détruit les Espèces* (Cuvier, 1825b). The 1822/1824/1825 third edition reprints of the earlier Cuvier fossil books presented the plates throughout the text, with some of the plates being foldouts. Plates were titled, and often included alphabetic lettering within the graphic. The drawings are remarkably detailed. One of the



more interesting plates depicts the fossilized remains of a plesiosaur unearthed in Lyme Regis, England by the first female paleontologist, Mary Anning. Cuvier's illustration of Anning's plesiosaur is shown in Figure 8.

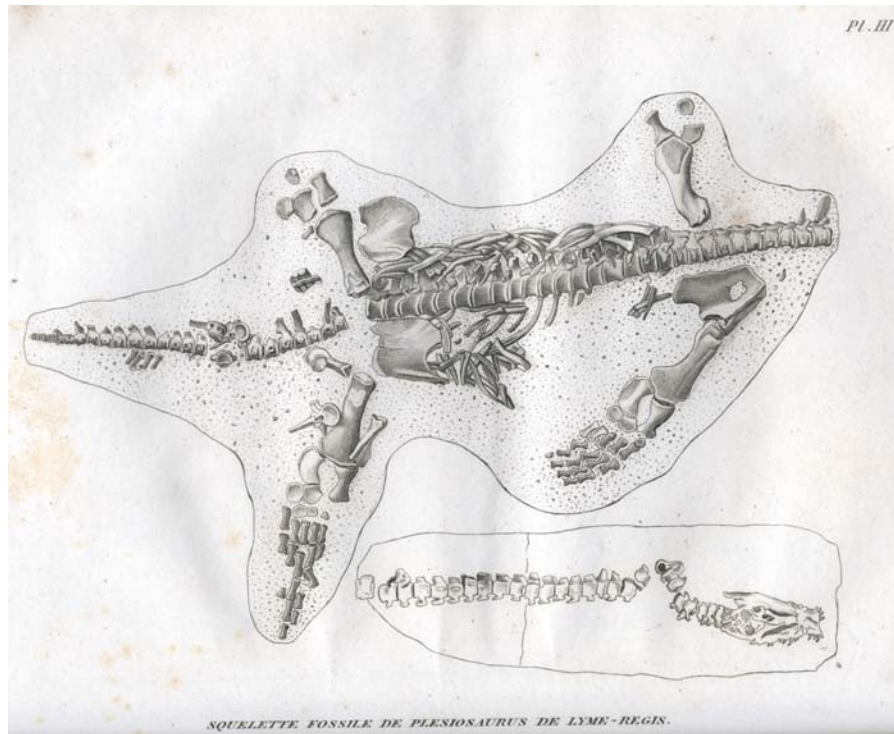


Figure 8: Plesiosaur remains, collected by the female paleontologist Mary Anning in Lyme Regis. Note the unusually fine detail of the drawing. (From Cuvier, 1825)

Although Cuvier's graphics are unquestionably detailed and informative, Cuvier, like other early paleontologists, was too narrowly focused upon fossil study to be considered a "general" geologist. Paleontological graphics, by themselves, are not conceptually representative of the early field of modern geology, since the modern field of geology is defined as that field of study beginning with accepted theories on the formation of the earth. The historical investigation into the early illustrations of modern geology mandates that graphics should be included that incorporate structure and strata of the earth. Cuvier's science focused on fossil investigations, and omitted – except within the collaboration of Brongniart and subsequent reprinting – the structural aspects of

geology. However, Cuvier's attention to detail and scientific discovery advanced his recognition as a respected contributor in the fledging science. Murchison remarked in Cuvier's obituary, "He it was who, removing from geology the incumbrance [*sic*] of errors and conceits heaped on it by cosmogonists, contributed more than any individual of this [19th] century to raise it to the place which it is assuming among the exacter sciences" (Woodward, 1911, p. 55).

### **Mineralogical Graphics**

Mineralogy, like paleontology, was well described long before James Hutton proposed his theories of uniformitarianism and the igneous origin of granite. Just as both biologists and geologists claim paleontology as a field of study, mineralogy is considered a discipline within chemistry as well as geology. Some of the early geologic texts are, therefore, characteristic of mineralogy texts and not foundational geological overviews. Some of the early mineralogy texts are discussed in the next sections.

**Parker Cleaveland.** Parker Cleaveland's (1816) text is proof that an author can faithfully describe crystallographic structure without utilizing a scientifically valid theory of the earth. Cleaveland was an advocate of the Wernerian method, and believed that all rocks were precipitated in an ancient ocean. Nonetheless, five plates inserted at the end of the text contain fairly accurate figures of crystal geometries. A sixth plate, described as a geological map of the United States, was missing from the book examined.

**William Phillips.** William Phillips' (1822/1978) collaborative book with Conybeare is considered a catalyst for geological study in England, and has been discussed previously. However, Phillips was an also accomplished mineralogist, and was considered by Gillispie (1959) to be the author of one of the best early geologic texts. The third edition of Phillips' mineralogy book (1823) contained simple line drawings of

crystals within the text, and also a foldout page of mineralogical apparatus near the end of the book.

**Thomas Thomson.** Dr. Thomas Thomson's mineralogy textbooks also emerged as geologic texts within the age of focus. Thomson published two volumes of mineralogy in 1836, and many crystallographic figures were incorporated in Volume I within novel wrap-around text. Thomson's graphics included alphabet lettering for identification of crystal faces. Phillips' measurements were often quoted, as in the case of the inclinations on an azurite crystal, presented in Figure 9.

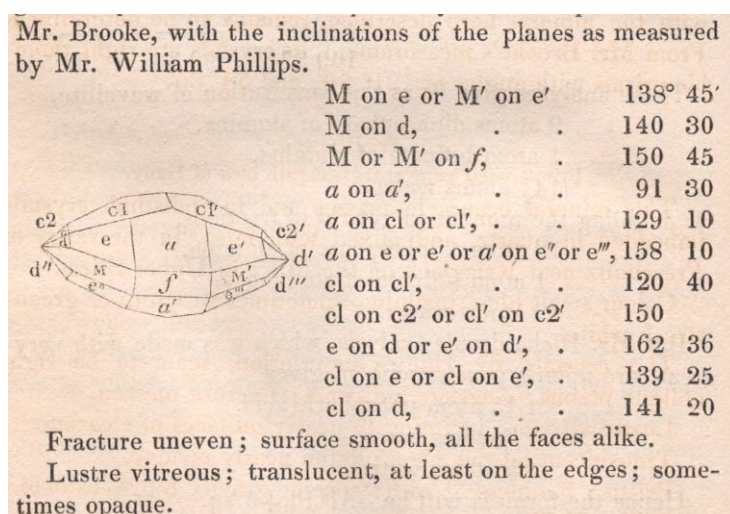
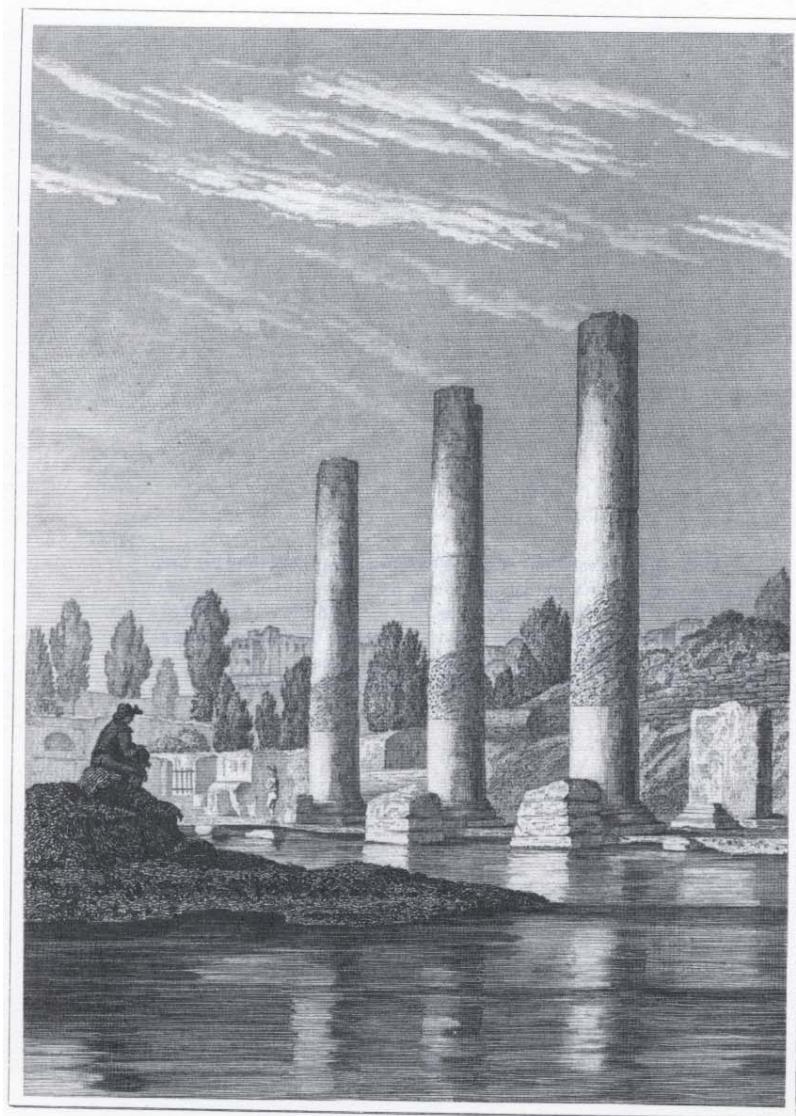


Figure 9: Structure of an azurite crystal, the figure of which is incorporated within wrap-around text. Phillips' measured inclinations are quoted. (From Thomson, 1836)

## Charles Lyell

Lyell, recognized as the person who did more for the acceptance of uniformitarianism than any other geologist, took great care in his preparation of demonstrations and illustrations to support his argument (Blundell & Scott, 1998). Lyell's skill in designing illustrations is quickly exemplified by his selection of a frontispiece. He chose a human artifact, the Temple of Serapis near Naples, which he had observed on his travels. This unusual illustration is presented in Figure 10. The



T. Bradley, Sc.

*Present state of the Temple of Serapis at Pozzuoli.*

*London, Published by John Murray, Albemarle St. June, 1830.*

Figure 10: Frontispiece for Volume I, *Principles of Geology*. This reduced facsimile version effectively illustrates past sea level changes with the mollusk borings on the columns. (From Lyell, 1830/1990)

temple columns show borings by marine mollusks, obviously made at a time when the sea level was much higher. Therefore, Lyell brilliantly linked

the human history with geohistory, classical scholarship with scientific research; it illustrated the power of actual causes, and the reality of crustal movements even within the short span of time since the Roman period; and it was a vivid demonstration that those movements had been in both directions, both elevation and subsidence, thus illustrating his conception of the Earth as a system in dynamic equilibrium. (Rudwick, 1998, p. 8)

Lyell illustrated his first volume of *Principles of Geology* with 33 figures and two map plates, one being a foldout. The figures, as well as the plate, were incorporated and described throughout the text. There is also a description of the plates and figures following the table of contents. With the exception of figure 2, a minimalist diagram explaining the sinuosity of rivers, all the other figures are illustrations of specific geologic examples. Lyell's No. 2 is shown in Figure 11.

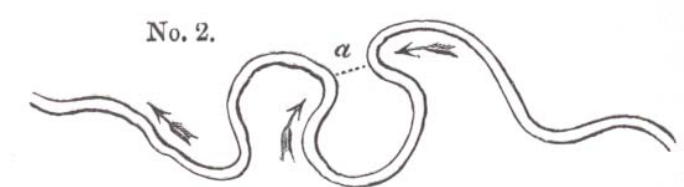


Figure 11: Sinuosity of rivers depicted. (From Lyell, 1830/1991)

Lyell's graphics can be classified into two major categories, with some overlap: (a) pictorial representations that are titled, but not often identified further with labeling; and (b) more diagrammatic representations, some in cross section, that include alphabetic or numerical labels within the graphic. Eight of the illustrated figures included direct labeling within the graphic. One of the more interesting figures in Volume I, Figure 15, incorporated both an overhead map view of the island of Santorin and a cross sectional view. It is presented in Figure 12. It is unclear what the numbers in the illustration represent, however, since there is no explanation of them in the text.

Lyell's second volume of *Principles of Geology* also included graphics, but in reduced number. The list of woodcuts, inserted at the end of the text following a



description of a foldout map plate, showed only nine graphics. However, three graphics – of mollusk eggs, seeds, and branches – included more than one figure. A vertical map of a chain of coral islands, and cross sectional views and pictorial representations of islands comprised the remainder of the illustrations.

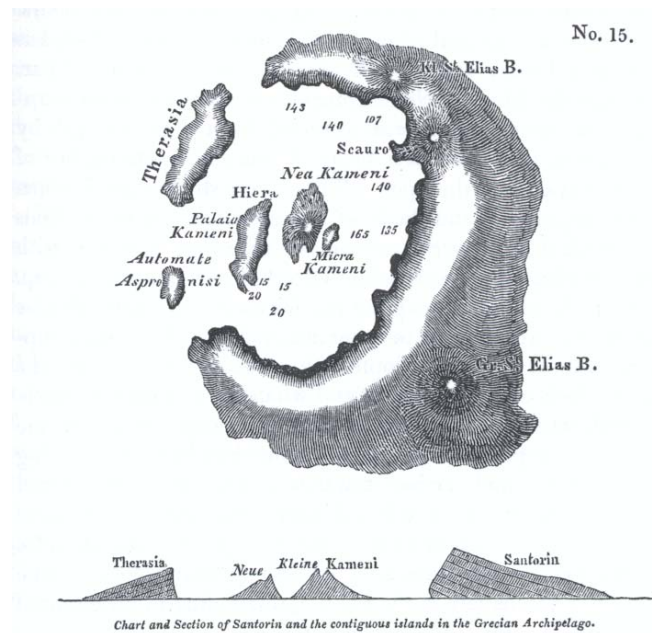


Figure 12: Map view and cross sectional view of the island of Santorin. Note the direct labeling in the illustration. It is unclear what the numbers reference. (From Lyell, 1830/1991)

Volume III, originally published in 1833, contained the most illustrations per volume of Lyell's *Principles of Geology*. The plates and woodcuts are listed in a section behind the table of contents; five plates and 93 woodcuts are listed. The first four plates are figures of fossil shells, with Plate IV showing microfossil shells. Plate V is a colored map of England. All five plates were inserted after the table of contents and the plate descriptions, but before the text began. The figures, however, were incorporated throughout the text. One figure followed a table, and two figures were even included in the glossary. Of the 93 figures, 65% have titles, 66% have alphabetic labeling within the

diagram, 55% have keys, and 25% incorporated direct labels on the graphic. Figure 45, reproduced in Figure 13, exhibits all four of these criteria.

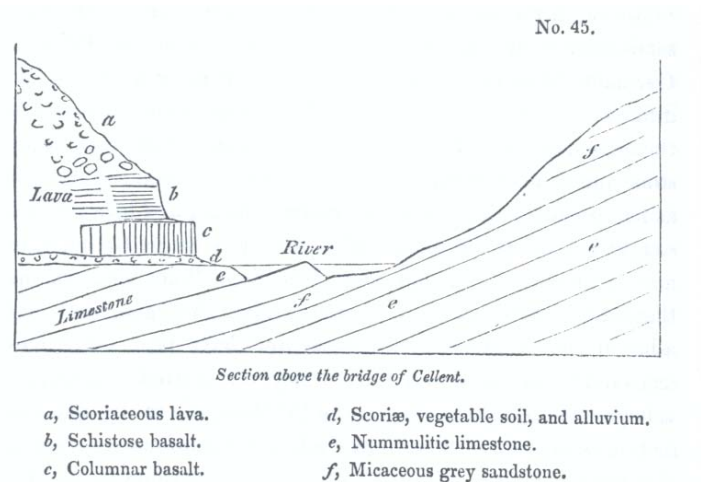


Figure 13: Cross sectional view above the bridge of Cellent. The graphic incorporates alphabet and direct labels, and includes both a key and a title. (From Lyell, 1833/1991)

As in the previous two volumes, most of the graphics represented specific illustrations of observed geology. There were, however, three exceptions. The two figures included in the glossary illustrated general geologic phenomena, while the first figure showed a generalized pattern of strata. Lyell, however, also included two figures in a discussion of the Valley of the Weald. In order to illustrate the anticlinal axis of the formations, a vertical exaggeration was necessary. Lyell then incorporated a diagram of true vertical scale below the first. These diagrams are presented in Figure 14.

Although Lyell was the most effective advocator of uniformitarianism, he still failed to persuade his colleagues of the theory's worth by the middle 1830s. This, in part, was likely due to Lyell's insistence that geologic evolution was non-directional. Lyell's failure to convince such geologists as Scopes and De la Beche resulted, according to Rudwick (1998), in a repackaging of the *Principles of Geology* in 1838 into a geohistorical version more suitable for general public consumption. It was with this

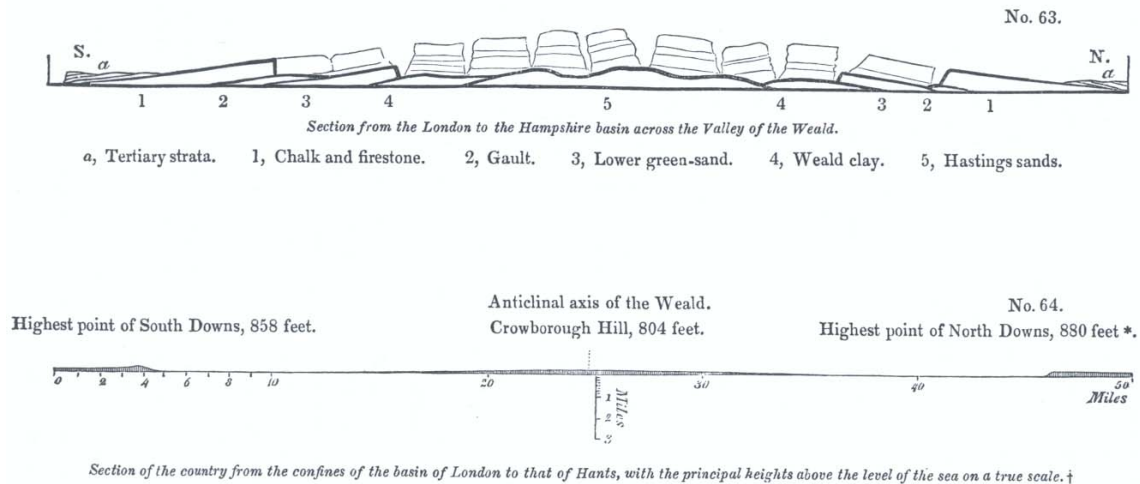


Figure 14: Figures 63 and 64 from Lyell's volume III, *Principles of Geology*. The figures illustrate the Valley of the Weald with vertical exaggeration (No. 63), and with actual vertical scale (No. 64). (From Lyell, 1833/1991)

recasting of the work that Lyell's original argument was divided into a treatise on causes, and the popular geohistorical version. Sadly, the original unitary conception had been lost (Rudwick, 1998).

The reception of Lyell's work differed across Europe according to country; whereas his influence on French geologic texts after the 1830s was negligible, Viccari (1998) noted that Lyell's influence on German scholars was observable in several texts. However, it is also interesting to note that among England's geologists, Lyell was still not unanimously accepted as a great geologist as late as 1905. Sollas (1905) argued that Lyell's concept of uniformitarianism was too narrow; the "zeal of the disciple outran the wisdom of the master [Hutton]," and by ignoring the advances made by geology's sister sciences (e.g., biology), Lyell "sinned against the light" (p. 2).

### Henry T. De la Beche

De la Beche emerged during the Pilot Study (Appendix A) as a contemporary of Charles Lyell. He authored several books during the age of focus, and was active in



many theoretical debates. De la Beche also managed to quiet William Smith's lamentation that the practice of geology was not in the same hands as those who theorized about geology. De la Beche managed to straddle both the social and working classes of geologists: De la Beche had social standing, and was admitted to the prestigious Geological Society of London. Fortuitously, when his fortunes faltered, he was hired as the first Director General of the newly formed British Geological Survey.

A gifted artist, De la Beche drew his own illustrations for publication, unlike the majority of geologists at the time. He was also a prolific geological writer. In 1824, De la Beche published *A Selection of the Geological Memoirs Contained in the Annales des Mines, Together with a Synoptical Table of Equivalent Formations, and M. Brongniart's Table of the Classification of Mixed Rocks Translated, with Notes*. In 1830, he published *Geological Notes*, and *Sections and Views, Illustrative of Geological Phænomena*. His *Geological Manual* was first published in 1831, and was later translated into French and German, published in the United States, and recast in different editions (De la Beche, 1831, 1832b, 1832c, 1833). *How to Observe Geology* was published in 1835. In 1834, De la Beche published *Researches in Theoretical Geology*, which was also subsequently published in the United States in 1837, and translated into French the following year. In 1839, he published a report on the geology of Cornwall and Devon. These publications are not the totality of De la Beche's works, however. Sharpe and McCartney (1998) listed a total of 63 publications that fell within the age of focus (1788-1840). De la Beche's first publication was listed as occurring in 1819, when he was only 25 years old!

De la Beche's books, on average, are very well-illustrated. The 1824 book incorporated a total of 11 plates; similar to most works before the 1830s, the plates were inserted before and after the text. Plate II, a hand-colored foldout map, was inserted at

the beginning of the text. The remaining plates were inserted in the book after the text. Nine of the plates were foldouts, while three were colored. One of the plates, Plate IV, is remarkable in that it presents a map view, with cross sectional elevations incorporated into the sides of the map. The cross sectional elevations show the dip of the strata. This plate is presented in Figure 15.



Figure 15: Map of the Val Canaria near St. Gothard, with two cross sectional views of the area. (From De la Beche, 1824a)

*Geological Notes*, published in 1830, contained only two graphics. Similar to most early geologic works, the plates were inserted after the text. One of the plates was a foldout. Plate 2 was important, however, in that its four figures were *educational*, and not simply illustrational. Although there was no description of the plate, the title read “Formation of Valleys.” This plate is presented in Figure 16.

De la Beche’s other publication in 1830 was *Sections and Views, Illustrative of Geological Phænomena*. This book can best be described as well-presented and beautiful

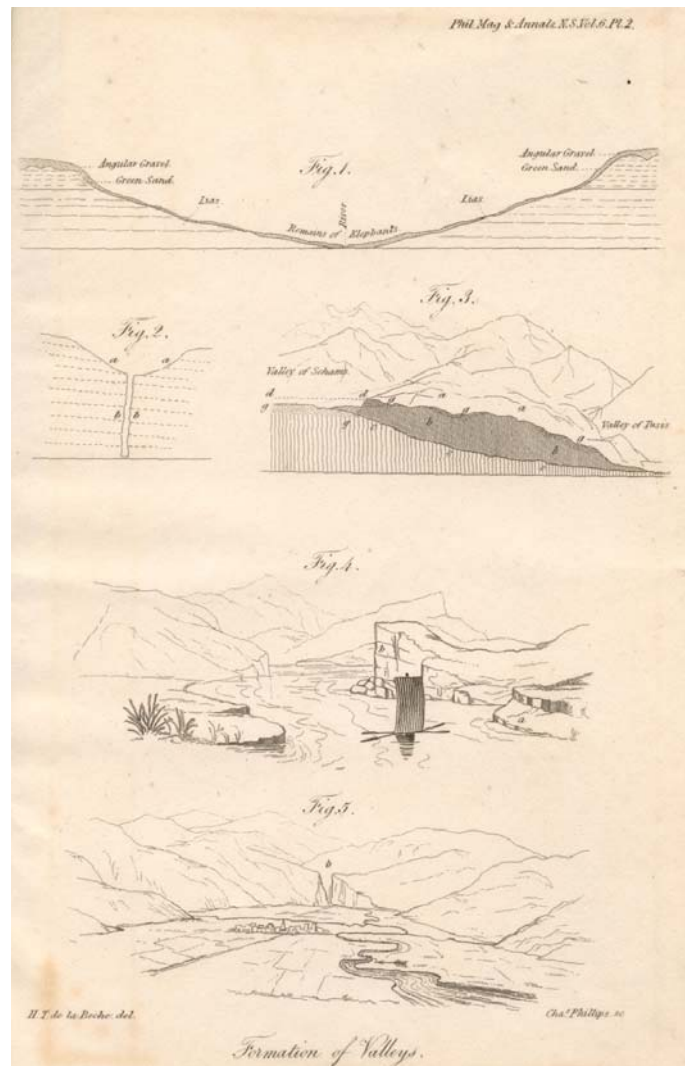


Figure 16: Five figures included in Plate 2, illustrating the formation of valleys. (From De la Beche, 1830b)

in its illustrations. There are a total of 40 plates, 24 of which are colored and 6 of which are foldouts. The plates were inserted after the text; the text described the plates in detail. Many of the plates illustrated cross sectional views, and keys were often included at the bottom of the plates. Examples of faults comprised Plate 5, which is reproduced as Figure 17.

Whereas Lyell included figures that explained vertical exaggeration and provided perspective for the reader in 1833, De la Beche preceded him in this graphic design with two diagrams in this 1830 text. Plate 2 presented seven figures with differences in

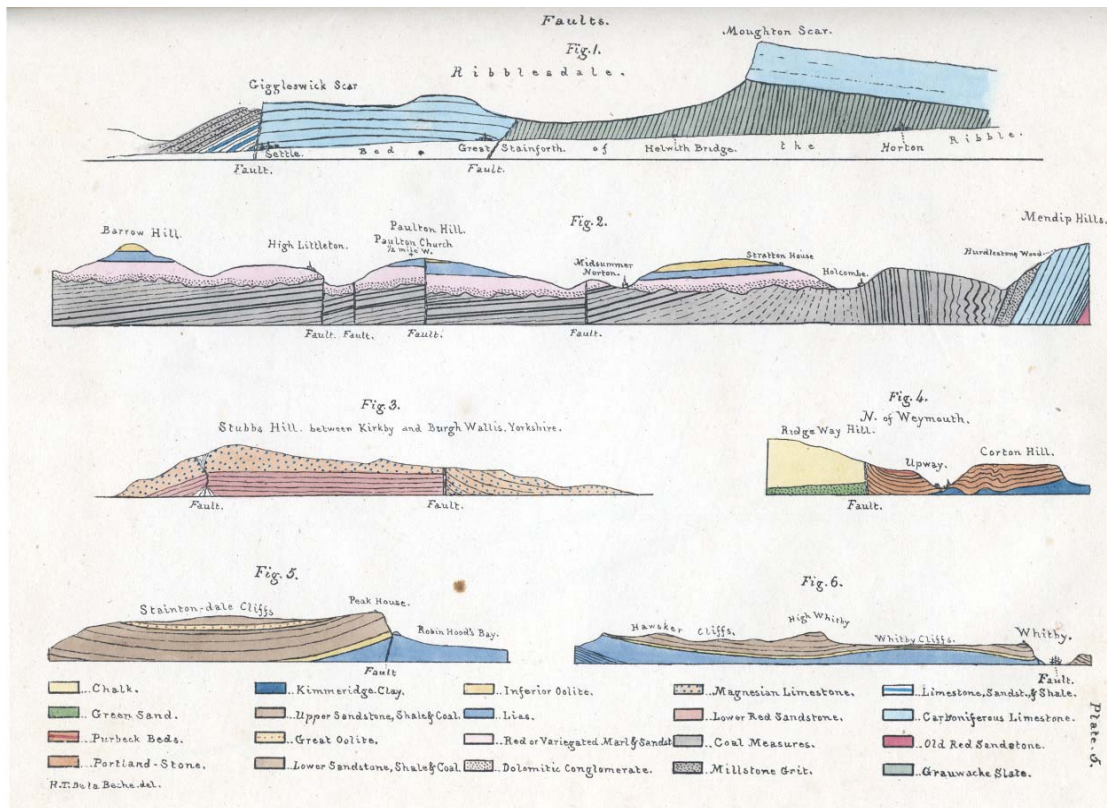


Figure 17: Illustrations of selected faults in six figures. Note the direct labeling, and color key. (From De la Beche, 1830e)

vertical exaggeration; the purpose of the plate is to educate the reader as to the need for portrayal of sections as close to natural proportions as possible in order to avoid confusion for the viewer. Plate 40, presented in Figure 18, illustrated relative distances in elevation on the earth compared to the whole of the earth, and also presented the relative size of the earth with respect to the sun.

De la Beche stated his purpose in *Sections and Views, Illustrative of Geological Phænomena* was to present facts, not theories. He believed that often too few facts were used to support theories, and from facts gathered, there always was the possibility of finding something new. De la Beche, therefore, wished to avoid theorizing in this book, and instead relied on factual representation. He stated,

The scarcity of the facts known too often gives the theorist a false security, and he hastens to conclusions upon the most meager data, without reflecting that a small addition to his present very limited

stock of knowledge may completely upset his speculations. The complacent manner in which geologists have produced their theories has been extremely amusing; for often, with knowledge (and that frequently inaccurate) not extending beyond a given province, they have described the formation of a world with all the detail and air of eye-witnesses. That much good ensues, and that the science is greatly advanced by the collision of various theories, cannot be doubted. (De la Beche, 1830e, p. iii)

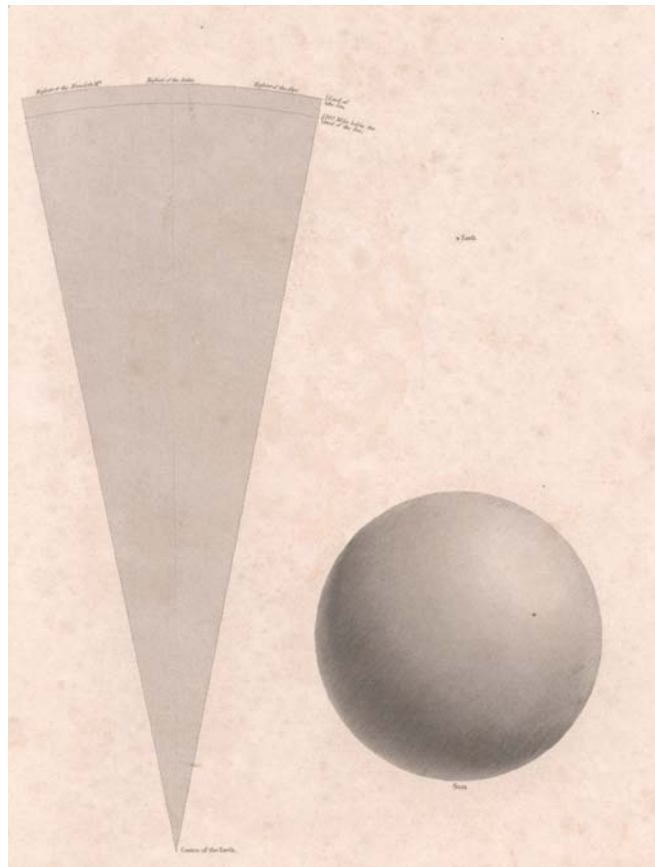


Figure 18: Relative size of earth's crustal features; relative size of earth to sun (From De la Beche, 1830e)

Therefore, in describing facts within this book, De la Beche assumed the role of a pioneer, a “laborious and comparatively inglorious” task that was ill-suited to “minds which desire to advance rapidly and grasp all at once” (1830e, p. vii). However, he seemed content with the task, and stated one of his purposes within the book was to “induce geologists to present us with sections more conformable to nature than is usually



done. Sections and views are, or ought to be, miniature representations of nature” (De la Beche, 1830e, p. vii).

The format of included graphics changed in De la Beche’s works with the 1831 publication of *A Geological Manual*. The figures were not incorporated as plates that were inserted after the text, but instead were incorporated within the text. The 1831 and 1832 English versions of the book included 104 graphics, noticeably more than the contemporary texts of Lyell. The French version of 1833 included three more graphics for a total of 107, and some of the original graphics were modified. The German version, however, was noticeably reduced in graphics, and only incorporated a total of 24 figures within the text. The graphics included cross sectional representations, pictorial diagrams, and, in the English and French versions, fossil illustrations. Interestingly, two of the added French graphics depicted ancient life. Figure 80, illustrating a plesiosaur, is reproduced in Figure 19. The presentation of the plesiosaur is typical of the early 1830s; the view is aerial instead of aquatic. Of note, this is the first geologic text encountered

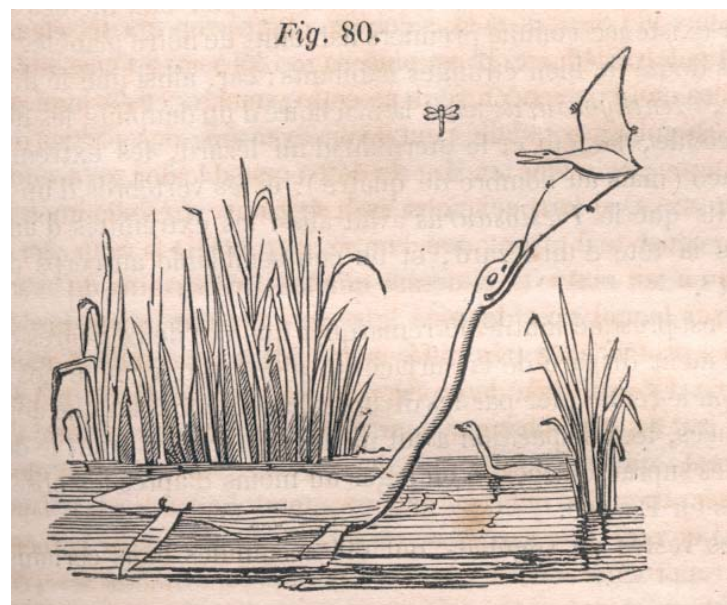


Figure 19: Reconstruction of ancient life showing a plesiosaur and a pterodon. (From De la Beche, 1833b)

that presented reconstructions of ancient life. According to Woodward (1911), Conybeare stated that De la Beche's *Geological Manual* was the best work of its kind. With three English editions, followed by American, French, and German editions, this was his most successful work (McCartney, 1977).

De la Beche's *How to Observe Geology*, published in 1835, increased the number of included graphics to 138. As in the previous *Geological Manual* books, the figures were directly incorporated within the text. Figures depicted cross sectional views, pictorial illustrations, and some brilliant educational analogies. One such figure, which has the potential to increase today's introductory geology students' understanding of geological strike and dip with a simple book demonstration, is shown in Figure 20.

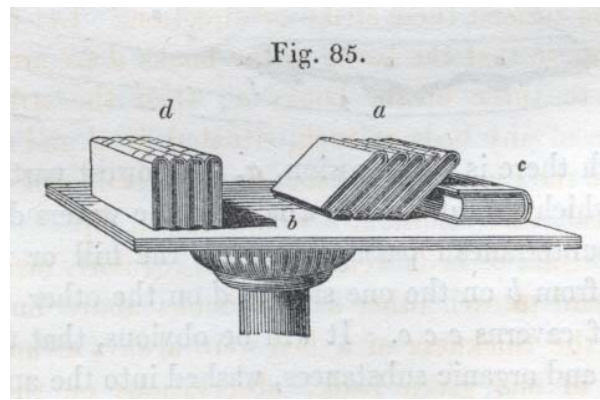


Figure 20: Graphic depiction of strike and dip analogy using books. (From De la Beche, 1835)

De la Beche's *Researches in Theoretical Geology* (1837e) incorporated graphics similar to those in *Geological Manual* and *How to Observe Geology*, except the figures were reduced in number to 46 total figures. The figures remained identical when the work was translated into French (De la Beche, 1838b). Graphics were concentrated toward the beginning of the book, and were sparse toward the end. Some figures again attempted to show proper geological perspective, and there was an effort to introduce additional physical variables in others. Figure 21 presents Figure 43, which showed

correlated distances from the coast with temperature and pressure variations in an effort to explain different marine communities. Although the description is found within the text, and no temperature and pressure numbers were recorded on the graphic, it remains one of the earliest attempts uncovered to include physical trends within an illustration in a geology text.

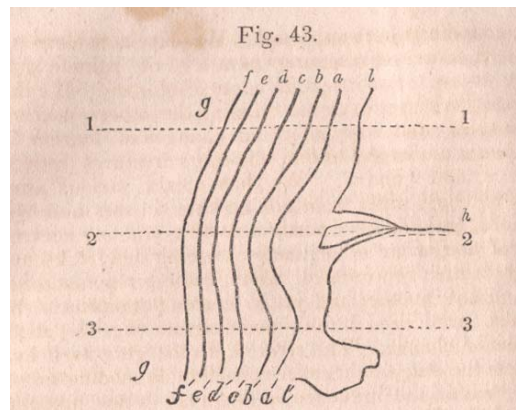


Figure 21: Coastline l – l', varying distances from coast, discussed in text as to pressure and temperature differences with resulting marine communities. (From De la Beche, 1837e)

*Researches in Theoretical Geology* was not only a discussion of existing geologic knowledge, but it presented new and original information as well (Woodward, 1907). The title of the book might lead the reader to suspect that De la Beche had abandoned his earlier ideas of presenting facts rather than speculating on theories. This, however, was not the case. De la Beche stated in the introduction that facts, whether supporting or opposing a position, should be brought forward; he was not so attached to the views in this text that he would not alter them if later explanations, better suited to the facts, were postulated (De la Beche, 1837e).

The 1839 *Report on the Geology of Cornwall, Devon, and West Somerset* included one foldout colored map inserted prior to the text, and 12 plates inserted at the end of the text, eight of which were foldouts. There were also 84 figures incorporated



directly into the text. Several of these graphics did not specifically illustrate observed phenomena; instead, their purpose was educational.

**Caricatures.** Geologic graphic illustrations were not the only outlet for De la Beche's drawing skills. De la Beche also drew caricatures – deliberate exaggerations of selected topics for comic effect. These caricatures give the viewer an unusual window on the geology, culture, history, and politics of the time. Rudwick (1975) located and described several of De la Beche's caricatures, which he interpreted as illuminating not only the social context of the time, but also the “substantive content of a scientific dispute of major importance” (p. 534). The dispute to which Rudwick referred was De la Beche's opposition to Charles Lyell's theories. In particular, De la Beche did not accept Lyell's scientifically invalid position that changes in the earth were cyclical, and that what had happened in the past might once again occur. De la Beche responded in caricature to Lyell's claims; the most famous of these drawings is entitled “Awful Changes,” and depicted ichthyosaurs and plesiosaurs in rapt attendance to the lecturing Professor Ichthyosaur. The setting is some time far into the future; the re-evolved ichthyosaur professor points to a human skull and notes that this *extinct* species was obviously a lower order animal, judging by its trifling jaws and insignificant teeth. Rudwick (1992) stated that De la Beche designed the caricature, a critique of Lyell's beliefs in non-directional evolution, as an “in-joke” for the Geological Society of London. This caricature is presented in Figure 22.

De la Beche directed several of his efforts at caricature against Lyell's theories. However, other topics were also the focus of his innovative, cartoon-based approach to theory critique. Several caricatures, for example, display De la Beche's attitude toward organized religion (McCartney, 1977). Geologists other than Lyell were also the topic of

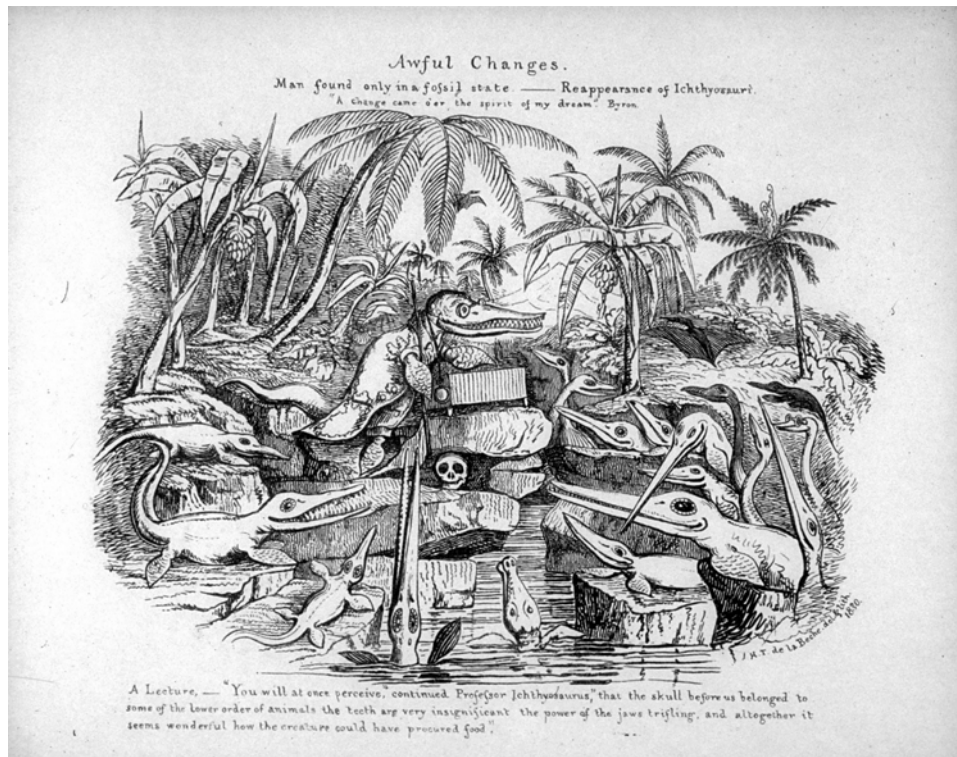


Figure 22: “Awful Changes,” a caricature by De la Beche critiquing Lyell’s non-directional evolution of the earth. (From De la Beche, 1830a; originally seen in Rudwick, 1992)

De la Beche caricatures as well. De la Beche apparently could not resist poking fun at his colleague William Buckland, who claimed that in all formations from the Carboniferous to the diluvium or Great Flood, the feces of extinct animals had been preserved. Buckland had even analyzed fossilized feces, or coprolites as he termed them, and reconstructed eating habits, as well as intestinal folds of the animals (McCartney, 1977). This comic temptation was obviously too great for De la Beche to resist, and circa 1829, he penned “Coprolitic Vision,” a caricature showing Buckland in full Oxford regalia, geological rock hammer in hand, before a large cavern. Inside the cavern, cave formations are all in the shapes of various coprolites, and all animals within are in the act of defecating. A photograph of this caricature is presented in Figure 23.

**Anning Association.** Henry De la Beche also has other laudable characteristics beyond his artistic skills that illustrate his exceptionality within the early geologic field.



Figure 23: De la Beche drew the caricature “Coprolitic Vision” to poke fun at the investigations of Buckland. (From De la Beche, circa 1829; originally viewed in this research project in McCartney, 1977)

During the age of focus (1788-1840), Mary Anning emerged as a woman fossil collector who made important contributions within the geological sciences. It is Mary Anning to whom the children’s tongue twister, “She sells sea shells on the sea shore” has been attributed (McCartney, 1977). Although Woodward (1907) called Anning “the most notable collector during the early part of the nineteenth century” (p. 115), most of her gentlemen peers did not consider Anning, as an “uneducated” woman, to be a prominent paleontologist (Monroe & Wicander, 1997). As a young girl, Anning collected fossils, or “curiosities,” with her father from the Lias cliffs near Lyme Regis, England. Upon her father’s death, Anning continued her entrepreneurial collecting endeavors in order to bring money into her mother’s household. Anning’s notable discoveries included the remains of an ichthyosaur, a plesiosaur, and a pterodactyl. The fossils she accumulated were sold to tourists who traveled to Lyme Regis, as well as to prestigious scientists and museums of the day. Winchester (2001) noted that the list of her customers was “like a roll call of the leading geologists of the day” (p. 109).

However, it was Henry De la Beche who appeared to recognize Anning's contributions to be those of a fellow scientist. De la Beche first met Mary Anning as a young boy when he moved to Lyme Regis. McCartney (1977) stated that De la Beche's interest in fossils was no doubt due to the Anning family's enterprise. De la Beche, unlike most male scientists of his time, acknowledged the contribution of this female paleontologist (Woodward, 1907). The friendship between Anning and De la Beche obviously lasted: According to Gould (1998), De la Beche drew an aquarium view of extinct animals, *Duria antiquior*, and had prints made to raise money for Anning when her financial situation deteriorated. De la Beche apparently emerges as a role model for the type of male needed in scientific fields, both then and now: one who recognizes the potential and advances female contributions in the sciences. Interestingly, although Monroe and Wicander (1997) lamented the fact that the geologic community had largely forgotten Anning, they also added to the problem. The third edition of their own text has eliminated Mary Anning's contributions to paleontology (Monroe & Wicander, 2001a)!

The historical reconstruction of ancient Dorset drawn by De la Beche on Anning's behalf exhibited another characteristic besides De la Beche's consideration for and acceptance of a female scientist. *Duria antiquior* is also innovative for its artistic viewpoint. Whereas most illustrators of the early 1800s portrayed marine organisms as either out of the water, or from the vantage point of the illustrator gazing down into the water, De la Beche drew this illustration so that the observer is viewing the scene laterally and partially *within* the water. Before the invention of the aquarium tank, artists either avoided, or were unable to conceptualize the organisms' "eye-to-eye, within-their-own environment viewpoint so 'naturally' favored today" (Gould, 1998, p. 67). Rudwick (1992) noted that De la Beche conceived this viewpoint two decades before the

Victorian aquarium craze. According to Rudwick, this is also the first publication of a scene depicting deep time. Furthermore, extinct organisms, some of which are shown in the act of defecation, were portrayed in a realistic landscape based on the scientific analysis of fossil remains. Rudwick (1992) believed this meant, for *Duria antiquior*, “its innovative character and historical significance can hardly be overestimated” (p. 47). It is presented in Figure 24.



Figure 24: *Duria antiquior*, a view of ancient life in Dorset by De la Beche. The view is unusual in that the observer is looking partially through water, instead of the traditional overhead view. (This watercolor was originally retrieved from Monroe & Wicander, 1997, but has now been replaced with a copy of the original retrieved in the National Museum of Wales. From De la Beche, circa 1830a)

**Other Educational Endeavors.** De la Beche was unique in early geology in that he was able to bridge the social class of geological theorists and the working class of geologists successfully. In the early 1830s, De la Beche worked at the self-imposed task of geologically surveying parts of Devon. Colonel Colby noticed his efforts in 1832, and De la Beche was officially asked to affix geological colors to county maps, which were

eventually published in 1834 and 1835 (Woodward, 1911). In 1835, Lyell, then President of the Geological Society of London, proposed the Ordnance Geological Survey, and De la Beche was appointed as its first director. Fortunately for the history of geology, this occurred at a time when De la Beche's personal fortunes began to dwindle. Woodward (1911) reported,

It is generally admitted that the first official or government survey of a country was instituted through the enthusiastic and personal labours of De la Beche. His methods were largely followed in other countries, and thus was created one of the most interesting and attractive of scientific professions. (p. 114).

However, although De la Beche was employed as a practicing geologist, he still maintained his social standing in the Geological Society of London, eventually becoming President of the organization from 1847 through 1849. De la Beche was also knighted in 1842, further proof that he maintained his social standing.

The Museum of Practical Geology was also largely established through De la Beche's efforts, as was the Mining Records Office, and the Royal School of Mines. Rudwick (2000) noted that all of these accomplishments represented one of the first major scientific investments made by the British government. Rudwick (2000) stated that De la Beche "exemplified strikingly the shift from amateur to professional careers among British men of science in the nineteenth century" (p. 840).

When the Museum of Practical Geology was officially opened by Prince Albert in 1851, Murchison described the event as the "first palace ever raised from the ground in Britain, which is entirely devoted to the advancement of science" (McCartney, 1977, p. 38). It had taken 16 years for this ambition to be realized.

There was an important and interesting shift in the focus of the Museum of Practical Geology during its formation: McCartney (1977) reported that the inclusion of

*teaching* in the museum's activities was added: De la Beche's first application to form the collection mentioned that specimens "should be arranged with every reference to instruction," although lectures specifically were not mentioned (p. 39). De la Beche did, however, propose lectures to be given at the Royal School of Mines. Some obstacles that he ran into were class-conscious restrictions. Although De la Beche intended that the school's main focus was the education of the mine owners and managers, he also believed that lectures should also be open in the evenings to those who were employed within the trade (McCartney, 1977). The evening lectures were wildly successful, even more so than the formal courses. However, McCartney (1977) noted that the appropriate lesson was still not learned:

Lord Seymour replied to the suggestion with the remark that the lectures to the working classes should be 'strictly confined to the classes of the persons mentioned, it having been found that they do not so readily attend lectures where persons in more easy conditions of life are intermingled with them.' (p. 40)

Although De la Beche was apparently willing to look beyond class restrictions, others of his era were not.

### Progression of Early Geologic Graphics

Investigation into initial geologic illustrations revealed that early graphics were not significantly multivariate and mathematical; most geologic texts still relied heavily on tables to present data. Whereas the majority of the earlier texts before the 1830s included only a few graphics that were inserted as plates before or after the text, the texts published during the 1830s tended to incorporate more graphics, usually inserted within the text. However, the beautiful use of color in some of the earlier texts (Bakewell, 1829; Parkinson, 1804, 1808, 1811; De la Beche, 1830e) notably disappeared in publications of the 1830s.

Most graphics included within early geology texts also displayed great similarities. Paleontological renditions, crystallographic sketches, and geologic maps were generally well-drawn, and show the advanced stage of the geologic specialties of paleontology, mineralogy, and cartography/geography. Mineralogy books seemed to be the most prolifically illustrated of the specialty geology texts; these texts incorporated numerous portrayals of crystal forms, faces, and angles. Illustrations depicting the formation of the earth – the crux of early modern geology – also exhibited many comparable features: Graphics were inclined to be illustrative of a particular field example, and seldom showed general tendencies. The graphics were descriptive, but seldom educational beyond the obvious depiction. Graphics were often cross sectional views, or pictorial representations of a natural landscape. The geologic illustrations in the age of focus (1788-1840) exhibit more similarities than differences.

However, some unusual graphic designs did emerge. Alexander von Humboldt's use of isotherms was far more mathematically advanced than other graphics in early geology, while De la Beche's use of scientific caricature was an effective tool for portraying the theoretical battles that engaged the early geologists. Bakewell, Lyell, and De la Beche designed some graphics for educational purposes as well as illustration. Differences also emerged in the number of graphics included in texts: De la Beche was the most prolific producer and user of graphics of the authors surveyed. Henry T. De la Beche also emerged as a geologist who practiced in the field, unlike many of his contemporaries who were gentleman theorizing about the new science. His promotion of practical geology museums and geology instruction further characterized his path-breaking approach to explaining early modern geology.



## Research Questions

In the age of focus of early geologic graphics (1788-1840), Henry T. De la Beche has emerged as a potentially under-recognized geologist whose use of geologic graphics categorized a visual approach to the science that has continued till this day. Not only did De la Beche appear to incorporate more figures and visual aids than other geologists of his time, but also he used an innovative, cartoon-based approach to encapsulate and communicate key geological issues of theory and practice at the dawning of geology as a science. He was a geologist who not only merely dabbled in the science as a gentlemanly past time; he managed to retain his social standing in the Geological Society of London while being employed and working in geology full time. He furthered the science of geology, and was the major advocate for the establishment of geological museums and schools whose roles included geologic education. McCartney (1977) noted that De la Beche is “almost unknown outside the geological world and today is little more than a name even to geologists, and yet his influence upon the development of the subject in this [20th] century has been profound” (p. vi). White’s (1978/1958) 13-page list of geologists’ biographies has no mention of De la Beche. Martin Rudwick, whom Stephen Jay Gould (1998) identified “an excellent paleontologist in his early career and now the world’s most distinguished historian of geology” (p. 67) also confirmed De la Beche’s ignored status. Rudwick (2000) noted that De la Beche’s

historical importance has long been obscured by the prominence given to his more flamboyant contemporaries; unlike them, he never received the standard Victorian ‘life and letters’ treatment, nor has he been the subject of a modern biography. With the publication of this guide to his massive archive at Cardiff [*The Papers of H. T. De la Beche (1796 – 1855) in the National Museum of Wales*], there is no longer any excuse for neglecting him. (p. 840)

Therefore, the focus of this research investigation became the exploration of Henry T. De la Beche's part in early geology and his forgotten geologic graphics, and their implication for the modern geology classroom.

### **Gaps in Geological Education**

The importance of this study lies not only in uncovering the role of Henry T. De la Beche and his graphics during the emergence of geology as a science, but also in the identification of successful geologic graphics that can be incorporated into the geology classroom today. Geology education appears to be under-researched when compared to the similar visual science of biology. An ERIC search (Educational Resources Information Center, website [http://ericir.syr.edu/Eric/adv\\_search.shtml](http://ericir.syr.edu/Eric/adv_search.shtml)) yielded 4,043 journal citations for “biology education,” but only 918 journal citations for “geology education,” less than 23% of the number of biology education articles! There also appears to be a descriptor problem when locating geology education articles within a database; many classrooms are identified with the more encompassing “earth science” title rather than “geology.” An ERIC search using “earth science education” garnered 1,049 journal citations, many redundant from the “geology education” search. The GeoRef database, a database commonly used by academic and practicing geologists, was also searched with the descriptor “geology education.” Only eight records were returned for this search, and the two citations returned from the past twenty years were news briefs. When the descriptor “earth science education” was entered, however, 258 records were located. Most of these records were from convention programs with abstracts. It is apparent that geology education/earth science education has not been fully researched, an oversight that should be corrected.

Use of graphics in the visual biology and geology classrooms also appears to be under-researched. Only 29 journal citations were located via an ERIC search for “biology education” and “graphics.” A similar 23 journal citations were found in ERIC when the descriptors used were “geology education” and “graphics.” Of these 23 citations, only seven citations did not appear to be centered on computer-assisted education. Computer-assisted geology education offers distinct advantages. However, the fact remains that many undergraduate introductory geology classes are large, often including 200 or more students. Large classrooms typically do not have space, or the equipment for all students to work within computer-assisted activities.

The descriptors “earth science education” and “graphics” yielded only 14 journal citations within ERIC. All but six of these citations were also located under the previous “geology education” and “graphics” search. Furthermore, most articles are not applicable to the introductory geology classroom. Since geology is a visual science, it appeared that much more research should be conducted as to effective graphic techniques within earth science and geology classrooms.

Interesting also is the fact that geology education does not appear to have a plethora of journals in which teaching techniques, methods, and innovations are discussed. *The Journal of Geological Education*, founded in 1951, is one of two periodicals discovered that is devoted to geology and earth science education. The journal subsequently became *The Journal of Geoscience Education* with the January 1996 edition, and is published by the National Association of Geology Teachers. This organization stated that its purpose “is to foster improvement in the teaching of earth sciences at all levels of formal and informal instruction, to emphasize the cultural significance of the earth sciences and to disseminate knowledge in this field to the

general public” (National Association of Geoscience Teachers, n.d.). However, investigation into this journal did not reveal a graphic-oriented style of presentation.

Investigation also revealed another journal, published in the United Kingdom, which is dedicated to geoscience education. The Association of Teachers of Geology (ATG) began publication of *Geology Teaching* in 1976. However, the journal’s name was changed in 1989 to *Teaching Earth Science*; around this time the organization’s name was also changed to Earth Sciences Teachers Association (ESTA). Many of the articles included in the journal discuss the United Kingdom’s national curriculum. However, there is also some discussion of fieldwork locations. Examination of the articles contained in *Teaching Earth Sciences* did not reveal many articles that discussed the visual aspect of the geoscience classroom.

### **Importance and Current Status of Geology Education**

In addition to the lack of research that characterizes geology and earth science education, there is a similar lack of respect for the geosciences in the curriculum requirements of most states. Whereas only 7% of the nation’s students take an earth or space science course, 88% of students take biology (Revolution in Earth and Space Science Education, n.d.). Fortunately, there has been recent progress in this area: Watson and Tucci (2002) reported that the latest victory for geoscience education occurred when North Carolina mandated earth and environmental science as one of three science courses for high school graduation. Roy (2002) also discussed the progress of a similar movement to make earth science part of the state science curriculum in Texas.

The most obvious question is whether geology or earth science is actually essential to students’ general education. Bybee and Pratt (1996) noted that the importance of the earth science discipline in the school curriculum was affirmed when it

was treated as a separate and distinct scientific discipline in the *National Science Education Standards* (1996). The National Science Foundation further confirmed the importance of geology and earth science education through its funding of the National Conference on the Revolution in Earth Science Education in June, 2001. One conclusion of the assembly was that we all – whether as professionals or private citizens – need to be literate in earth science in order to make important decisions concerning resource management and emergency planning (Revolution in Earth and Space Science Education, n.d.). The geosciences are integrated sciences, and fuse the disciplines of chemistry, biology, physics, meteorology, and oceanography in the classroom. The importance of geology and earth science as integrated sciences, fueled by recognition from national standards, has promoted the recent development of programs implementing geosciences in the classroom. Smith (2002) reported that recent geoscience opportunities and proposals include EarthScope, a project to develop an instrument network for the North American continent; “Earth Science by Design,” a program to construct, in conjunction with middle school teachers in earth science, curriculum units that revolve around the major concepts and integrate *visualization* tools within the classroom; and online opportunities, such as American Geological Institute’s Professional Development Web sites and the Earth System Science Education Alliance, which promote inquiry-based instruction and assessment in the geosciences. Therefore, it appears that a new awareness and understanding of the importance of geoscience education exists. Due to the nature of the visual aspect of the science, success in the classroom can be partially attained through the effective use of graphics. It is hoped that this investigation into Henry T. De la Beche’s graphics and their application for the modern geology classroom will contribute to the knowledge base for effective graphic use in geology education.

## Chapter 2: Review of Literature

Investigation revealed that geology education has not been fully explored. Gaps were observed, and these gaps are especially pronounced in published research investigating the use of graphics in the geology classroom. Since geology is a visual science, advances in geology education can proceed through an improved use of diagrams, maps, and other illustrations. Through the phase-investigating research into the graphic innovations of Henry T. De la Beche, illustrations were uncovered that have the potential to improve visual geology education. Therefore, it was important not only to delineate the qualities and characteristics that create an exceptional graphic, but also to specify the approach in which these graphics might be used for classroom success.

As the initial investigation into early geologic graphics progressed, a thorough literature search was also conducted to identify why early geologic graphics are important in the modern geology classroom, and how they can be productively integrated. The Theory of Human Constructivism and Paivio's dual coding theory offer strategies for effective inclusion of graphics within the geology classroom, while Tufte's theory of graphic excellence provides guidelines for graphic classification and identification. Specific research studies also revealed links between graphics and texts, as well as between graphics and student learning. Since the proposed research deals with historical graphics, the History and Philosophy of Science in Science Teaching (HPSST) literature is important because it addresses the effectiveness of using historical products and narratives within the classroom. Finally, additional discussion of the period of early modern geology that this study utilized seemed warranted. Social constraints affected publishing geologists, while the evolution of printing techniques may have had direct consequences for illustrations included in a text.

Therefore, several theories directly affected the investigation into the role of early geologic graphics and their subsequent inclusion and implications within the modern geology classroom. As noted earlier with the Howe-Russell Geoscience example, a graphic with much information does not necessarily educate viewers. Graphics must be successfully incorporated in the classroom, and students must be taught how to effectively utilize them. Consequently, the Theory of Human Constructivism as proposed by Novak (1977), and expounded by Mintzes, Wandersee, and Novak (1998, 2000), has direct implications for this research as a learning theory for success within the science classroom. Novak's theory promotes meaning over memorization, quality over quantity, and awareness over understanding.

Paivio's dual coding theory, which supports the effectiveness of multiple channel communication – communication incorporating both verbal and visual cues – is also directly relevant for the use of graphic representations as teaching tools within the classroom. The determination of whether or not an early geologic graphic is well designed can be made in accordance with Edward R. Tufte's theory of graphic design. Tufte discussed numerous variables a successful graphic should exhibit or incorporate; it is through Tufte's principles that a graphic is judged as effective or otherwise in this research study.

Although graphics do have a history of being incorporated into science classrooms, there does not exist a large body of research directly addressing graphic use in these classrooms. However, journal articles and five dissertations were identified that have some relevance to this topic, and their pertinent information is discussed.

The History and Philosophy of Science in Science Teaching (HPSST) is an educational movement that also has direct implications for this research. The National

Academy of Sciences (1995) included the nature of science and the history of science as part of the National Science Education Standards. In addition to being geologically relevant as effective teaching tools today, historical graphics could also possibly enrich the classroom by revealing social, cultural, and political climates of their times. Using Matthews (1994) as a guideline, the benefits of using HPSST in the geoscience classroom are identified.

Finally, the Golden Age of Geology is used as a guideline for the definition of the age of focus for this study. It is the concluding year of the Golden Age of Geology that is utilized as an arbitrary end for the period of early modern geology. Therefore, this delineation is discussed more thoroughly as a criterion of reference.

### Theory of Human Constructivism

Novak, Mintzes, and Wandersee (2000), in *Assessing Science Understanding*, discussed the foundational basis of the Theory of Human Constructivism. Humans have an enormous capacity to make meaning, and science is best taught, and understood, when this meaning-making capacity is accessed. A teacher should take the role of facilitator, arbitrator, or middleman in the construction of shared meaning in the classroom. This shared meaning should have potential value; students should be able to critically evaluate knowledge and value claims with this shared meaning. As students progress, and incorporate more and more knowledge into their conceptual structures, their knowledge structures become more powerful. Students can actually challenge existing knowledge and value claims. With such a learning situation, assessment cannot simply rely on standard techniques of the past. The authors mentioned that knowledge could not simply be measured by a formalized comparison among students, and a single alphanumeric score could not adequately represent conceptual change.



## **An Alternative to Previous Theories of Learning**

Wandersee, Mintzes, and Novak (1994) stated that the Theory of Human Constructivism was offered as an alternative to the Piaget's theory of learning stages. Piaget's stages include sensorimotor, preoperational, and more importantly for the classroom, concrete operational and formal operational. Gowin (1981) also noted that the Theory of Human Constructivism offered an alternative to Dewey. Whereas Dewey believed that social and moral matters would find their way into the classroom with the teaching of intellectual science, Gowin stated that this had not occurred. Gowin believed that it was time to stop separating fact from value in the classroom, and the Theory of Human Constructivism is a vehicle for doing so.

Although "constructivism" is a term currently in vogue, Mintzes, Wandersee and Novak (1998) clarified their use of the term. The constructivism they advocated was a moderate-position constructivism. Basic ontological beliefs of their theory include the existence of an external and knowable world. Students add to their knowledge framework by constructing heuristically powerful explanations through prolonged interaction with objects, people, and events. The goal of education is shared meaning.

Novak (1998) noted that students who have well-organized and integrated frameworks of knowledge are meaningful learners. It is our job, as teachers, to define and clarify concepts and propositional statements for our students. Novak (1998) stated,

It became increasingly evident that in educating 'we reap what we sow.' Instruction and evaluation emphasizing or favoring rote learning strategies lead to little improvement in learner's usable knowledge structures, whereas the reverse was the case when meaningful learning strategies were encouraged or favored. (p. 12)

## **Founding Principles of the Theory of Human Constructivism**

The Theory of Human Constructivism is based upon the principles of Ausubel (1963, 1968). Ausubel's principles include meaningful learning, and the well-known statement that the most important factor in instruction is what the learner already knows. Wandersee (1986) restated this as, "The most important things students bring to their science classes are their concepts" (p. 581). Ausubel distinguished between subsumption and superordinate learning. Subsumption learning occurs when the learner must incorporate new, more specific knowledge that he or she has encountered; this knowledge is subsumed into an existing cognitive framework. When a learner encounters new knowledge of a more general nature, the learner must reorganize his or her conceptual framework, with the new knowledge as an organizing concept. This is referred to as superordinate learning. Ausubel noted that superordinate learning is probably linked to creative behavior, as well as moments of insight. Ausubel further distinguished between reception learning, a passive process, and the more desirable discovery learning, an active learning process.

Mintzes and Wandersee (1998) discussed Ausubel's construct of meaningful learning. Meaningful learning, the opposite of rote learning, is nonverbal, and nonarbitrary. It results in substantial incorporation of new knowledge into the learner's conceptual framework. Three conditions must be present for meaningful learning to occur: the knowledge must have value or potential value for the near future, the student must already have sufficient concepts in place to anchor the new knowledge in his or her conceptual framework, and the learner must actually choose to incorporate the knowledge into his or her conceptual framework. Mintzes and Wandersee noted that meaningful learning could take place in discovery learning situations, as well as within well-

organized instruction in a more traditional setting. With knowledge and domain-specific pedagogical content, teachers have the ability to transform the classroom.

The Theory of Human Constructivism was seen to be the only theory of learning that was based on cognitive theory, included expansive epistemology, and included a set of tools for the classroom teacher as well as the learner. This theory combines meaningful learning, knowledge restructuring, and conceptual change. Implications of the theory include the idea that the way scientists learn should be no different from the way students learn. Knowledge is seen as idiosyncratic and dynamic.

### **Variables in the Theory of Human Constructivism**

**Role of the Teacher.** The role of the teacher is that of facilitator or middleman in the construction of shared meaning in the classroom. The teacher should incorporate as many active learning situations as possible. Wandersee, Mintzes, and Novak (1994) noted that the teacher not only needs knowledge of the subject being taught, but also domain-specific pedagogical content knowledge (PCK) in order to better present the material in a meaningful learning situation to his or her students. Teachers can employ laboratory exercises, cooperative group situations, and metaphorical analysis in order to facilitate knowledge restructuring and conceptual change in their students.

**Role of the Student.** Students must be willing to incorporate new knowledge into their existing frameworks of knowledge. Furthermore, students should come to understand the role of the individual, as well as the role of a supporting (or not) society in which the knowledge was generated. Since students are individuals, they bring unique frameworks and preconceptions into the classroom.

**Role of Conceptual Framework.** Often, the conceptions students bring to science class are limited, confused, or incorrect. Wandersee, Mintzes, and Novak (1994)

preferred to call these conceptions alternative conceptions, since this was a term that was respectful to the learner. (Another term proposed by Good in 1991 for the misconceptions students bring into the classroom was “prescientific conceptions;” however, the term “alternative conceptions” now seems to have firmly established itself in the literature.) Alternative conceptions are very resistant to change, and traditional classroom techniques typically do not work well in overcoming them. Wandersee, Mintzes, and Novak stated that alternative conceptions cut across various boundaries, including gender and age. These alternative conceptions were seen to be a product of many influences, including peers, mass media, and society.

Whereas Wandersee, Mintzes, and Novak (1994) believed that the identification of students’ alternative conceptions would aid the teaching process, McClelland (1984) voiced a contrasting view. McClelland believed that often students do not reflect on their alternative conceptions, and so what a teacher might mistake for an alternative conception might, sometimes, be a non-differentiated conception. Therefore, McClelland did not see a true advantage for teachers to try to identify alternative misconceptions in their students.

**Role of Conceptual Change.** Although traditional classroom techniques do not work well in causing the extinction of alternative conceptions, the Theory of Human Constructivism’s meaningful learning offers a vehicle for conceptual change. Students who have highly differentiated and integrated concepts are meaningful learners. Meaningful learners are further identified by their ability to plan, monitor, regulate, and control their learning. Metacognition, as defined by Gunstone and Mitchell (1998), is knowledge, awareness, and control over the learning process. Conceptual change is most likely to occur through students’ metacognition of their learning activities.

**Role of Curriculum.** Mintzes and Wandersee (1998) did not believe that the standard curriculum observed in most schools would promote meaningful learning. Instead, the authors advocated a policy of “less is more.” A small and carefully selected set of concepts should be taught, and taught thoroughly in a meaningful way. Duschl (1990) concurred with this idea: Reducing the number of concepts taught in a science class allows higher order thinking processes – such as in-depth analysis, synthesis, and evaluation – to occur in the classroom. The reduction of the volume of material to be covered in the classroom was, in fact, one of the most pressing dilemmas to be solved in the development of National Standards for earth science education (Bybee & Pratt, 1996). The Theory of Human Constructivism can be used successfully to expand a smaller number of important concepts in the classroom because it advocates quality over quantity, meaning over memorization, and understanding over awareness.

**Role of Teaching Tools.** Several tools are available to the teacher in the Theory of Human Constructivism, including many graphic tools. Advance organizers are important, and may include concept maps (Trowbridge & Wandersee, 1998), concept circles, Gowin’s research Vee (Gowin, 1981), and K-W- L charts (Carr & Ogle, 1987). Many of these techniques are advocated for gifted classrooms, as well as for encouraging creativity in the classroom (Starko, 1995). Other tools available to the teacher include confrontation techniques, cooperative learning groups, storytelling, and use of metaphorical analysis. Interactive historical vignettes can bring history of science into the science classroom as well (Wandersee & Roach, 1998). Good and Berger (1998) also noted that the Internet now offers access to a world of knowledge, and is a potentially powerful tool in the classroom.

## **Cautionary Notes on the “Constructivism” Term**

Good, Wandersee, and St. Julian (1993) cautioned about the use of the term “constructivism.” It was believed that the term had become an umbrella, which sheltered many different philosophical beliefs. In particular, the authors noted that people with very different ontological beliefs as to the nature of knowledge and reality use the term. Matthews (1999) further cautioned against the term, and noted that we must specify the particular type of constructivism advocated. Authors should state whether the constructivism is a philosophy, a form of social constructivism, or a learning theory. With this in mind, the Theory of Human Constructivism is specified as a theory of learning, and not a philosophical or social theory.

## **Paivio’s Dual Coding Theory**

Just as the Theory of Human Constructivism provides guidelines for successful teaching and meaningful learning in the classroom, Paivio’s research into the dual coding of information also has applications to increase success within the classroom. Although historically the dominant view in America was that meaning was formulated through verbal association, Paivio (1971) investigated the significance of both verbal and visual, or imagery, processes. Both verbal processes and images were viewed as coding systems that were linked to experiences. However, verbal labels are not necessarily only invoked by language, and images are not only necessarily invoked by objects. Instead, Paivio believed that there exists an associative relationship in that an object may invoke a verbal label, and language may invoke an image.

## **The Dual Coding Theory**

The beginnings of Paivio’s dual coding theory lay in the conceptual-peg hypothesis of word imagery effects on recall (Paivio, 1991). The conceptual-peg

hypothesis uses an initial rhyming technique (one-bun, two-shoe, three-key), into which words that are to be memorized are visualized within the schema. For example, Paivio (1991) used the example that if lamp was the first word to memorize, the learner could imagine a lamp as the filler between hamburger buns. Recall would later proceed via one-bun, which then subsequently would invoke the image of lamp. This technique has been used successfully to memorize long lists of words. This mnemonic technique requires dual coding because nonverbal images are generated from words during the learning of lists, and then regenerated from verbal cues in a recall stage. Finally, the nonverbal images are decoded into words.

**Assumptions of the Dual Coding Theory.** Paivio (1974) stated that the most general assumption of the dual coding theory is that the verbal and nonverbal information systems are distinct, but interconnected. Although these systems are functionally independent, there is some connection in that activity in one system can trigger activity in the other. The imagery system is specialized to represent and process information of nonverbal cues and objects in a direct, analog fashion. Likewise, the verbal system is also specialized to represent and process information in linguistic units. Neither system is static; both systems are dynamic, and within a system, information can be reorganized or manipulated.

Paivio also believed that the processes are not necessarily conscious. Furthermore, the information in one system does not automatically predict the information in the other. Each system can be active independently of the other, or activity from one system can invoke activity from the other system.

**Processing Operations.** There are three possible processing operations in the dual coding approach. Representational processing occurs when verbal stimuli activate

representation via logogens within the verbal system, or when nonverbal stimuli activate representation of imogens within the nonverbal system. Referential processing transpires when the verbal system accesses or activates the nonverbal system, or vice versa.

Associative processing arises when processing occurs entirely within the verbal system or nonverbal system.

### **Meaning and Memory**

Paivio (1971) proposed that meaning “coordinates imaginal symbolic processes with concrete stimuli and symbolic tasks involving them, and verbal symbolic processes with both concrete and abstract stimuli or tasks” (p. 50). This definition differed from the contemporary understandings of meaning in that Paivio’s definition included nonverbal imagery as a system that reflects meaning; Paivio also emphasized concrete objects and pictorial representations. The two systems were separate, but interconnected; additive effects on memory recall verified the independence of these two systems. Paivio and Csapo (1973) discovered that repeating a word as a picture, or repeating a picture as a word doubled recall, but repeating a picture twice or a word twice did not double recall. The researchers also noted that the contribution of imagery on memory recall was substantially higher than that of verbal.

Paivio (1971) found that the best predictor of memory performance was the imagery-concreteness of the stimulus. Memory increased from abstract words to concrete words, with a further increase in pictorial representation. Paivio also confirmed that classical memory techniques were valid as memory aids. However, he found it difficult to separate the contributions of the verbal and imaginal mediators in learning and memory in his early research. Although the functionality of the two systems was accepted, the operation of the systems was not understood.



## **Applied Research**

In a review of 55 experiments, Levie and Lentz (1982) focused specifically upon the effect of illustrations on learning verbal information presented in the text. Their analysis revealed that within 46 comparisons produced from 23 studies, all but one comparison showed that reading text with relevant illustrations was superior to reading non-illustrated text; 39 of these comparisons produced results that were statistically significant. The presence of illustrations had no effect, however, on the learning of the verbal material that was not depicted in the illustrations. In research studies where a combination of illustrated and non-illustrated text existed, 38 of the 48 comparisons resulted in favorable response to illustrations. Levie and Lentz believed the overall conclusion was clear: Obviously illustrations that are highly relevant to the text facilitate the learning of the accompanying verbal material.

Mayer and Gallini's (1990) research also verified the value of verbal text and illustrations. Specifically, the use of text and explanative illustrations – those illustrations aimed at serving an interpretive function – verified that parts-and-steps graphics consistently improved performance on recall of conceptual information and creative problem solving, especially among students with little prior knowledge. These parts-and-steps illustrations conveyed both the visual aspect of the problem, in this case a braking system and a pump system, and the accompanying verbal description. The researchers stated that visually based instruction had the potential to promote students' understanding of science.

Mayer and Anderson (1991) further confirmed the importance of combined visual and auditory instruction. In their research, they observed that groups that received verbal instruction with computer animation outperformed groups that received either verbal

instruction before animation, animation alone, or words alone. It therefore appears that verbal instruction combined with visual instruction is more successful than either a solitary visual or verbal approach, and that both approaches should be utilized simultaneously within the classroom.

### **Multiple Channel Communication**

Whereas students in the past learned by comprehending through words, Gioia and Brass (1985 – 1986) believed that modern students were more visual in their approach. The authors noted that the average television usage was 7.3 hours per day in the early 1980s. The students of today are comfortable with visual experiences, as well as changing channels with remarkable speed. Gioia and Brass alleged that, as a result of their television and video game experiences, modern students were characterized as predominantly visual as opposed to verbal learners. The incorporation of visual imagery in the classroom could teach students more effectively in both the verbal and visual modes. The research of Paivio and Csapo (1973) supports this view. Additionally, Paivio's dual coding theory predicts that successful instruction results when students build representational connections for verbal and visual representations, as well as referential connections between the verbal and visual representations (Mayer & Anderson, 1991).

### **Implications of the Dual Coding Theory for Education**

Visual encoding of material has been ignored in the past, but has been found to be even more effective than verbal cues in contributing to memory and retention. A combined visual and verbal presentation of material should be even more effective at increasing recall and retention because the material is dual coded by the brain (Paivio, 1971, 1991). Paivio believed there were several implications of the dual coding model

with regards to education. Mnemonic aids that relate new knowledge to a familiar part of students' knowledge were encouraged. Paivio also suggested that it was more effective to begin with concrete and specific examples of ideas and then move to abstract or general ideas.

### Tufte's Theory of Graphic Design

Paivio's research supported the use of both verbal and visual tools within the classroom. However, not all visual tools are of equal value. Yale Professor Edward R. Tufte is the author of three self-published books on graphic design: *Visual Display of Quantitative Information* (1983/2001), *Envisioning Information* (1990), and *Visual Explanations* (1997). In these three volumes, Tufte provided general rules and rationales for effective graphic construction, as well as guidelines through which the effectiveness and quality of graphics can be judged.

Tufte's first book, *Visual Display of Quantitative Information*, is a book about "pictures of numbers." The second Tufte volume, *Envisioning Information* (1990) is about "pictures of nouns," or concepts, and the layering of information within graphic design. The third volume in Tufte's series is *Visual Explanations* (1997), which is about "pictures of verbs" or processes, and causal relationships. Tufte is also reportedly at work on a fourth volume to his theory of graphic design, which will be about the aesthetics of information, or "pictures of adjectives and adverbs" (Lucas, 2000). If past history is any indication, this volume should be available to the public in 2004, seven years after the publication of the third volume.

Embedded in Tufte's three-volume work are several basic principles for effective graphic representation. The discussions of 10 of the core values that were extracted by this researcher follow, as well as rationales for their importance.

### **Core Value One: Show the Data**

The first core value, and the focus of Tufte's theory of graphic design, is that the designer needs to present the data. The most important function of a graphic, according to Tufte, is to provide the viewer with easy access to the data. The viewer should not have to dissect graphical design in order to locate the information. Tufte also noted that "garbage in equals garbage out." A good graphic is determined by the quality of data. If the data are not of good quality, the graphic will not be either. A viewer should have access to the data in order to determine whether the data being represented are valuable.

### **Core Value Two: Data Should Be Presented Truthfully**

The viewer of a graphic should not have to discern whether or not the graphic designer was deliberately trying to deceive. As graphic designers, we essentially have an ethical responsibility for factual presentation of data. The presentation of the data should follow the nature of the data. If only two dimensions are represented by the variables, only two dimensions should be depicted in the graphic. Tufte exposed several examples of three-dimensional representation of two-dimensional variables. Since a two-dimensional increase is an increase in area (length times width, for example), this is not equivalent to a three-dimensional increase in volume (length times width times height). Graphics that employ three-dimensional pictorial representation for two-dimensional variables portray a false increase or decrease of the variables.

### **Core Value Three: Complex Data Sets Are Good**

Tufte believed that a graphic designer should not underestimate the intelligence of his or her audience. This is directly opposite from the philosophy of P. T. Barnum. Tufte (2001) stated, "If the statistics are boring, then you've got the wrong numbers. Finding the right numbers requires as much specialized skill – statistical skill – and hard work as

creating a beautiful design or covering a complex news story” (p. 80). Complex data sets allow the viewer to access great amounts of information. The viewer can then decide which variables or parameters are important for investigation. The best graphics portray the greatest amount of information in the least amount of space.

#### **Core Value Four: Best Graphic Designs are Multivariate**

Tufte believed that the best graphic designs were those that concentrated data in a relatively small space. Besides multivariate designs, or designs utilizing many variables, Tufte also promoted the use of layered designs, small multiples, and macro/micro designs. Layered designs present many levels of information within various portions, or layers, of the graphic. Small multiples are extremely efficient for the viewer: Once a viewer has decoded the graphic vehicle, he or she has immediate access to large data sets since the vehicle remains the same with each presentation. Macro/micro designs also present large quantities of information. In them, information is presented on both a large scale (the macro level), as well as in greater detail (the micro level). Tufte identified Maya Lin’s Vietnam memorial wall as an excellent example of a macro/micro design.

#### **Core Value Five: Improve Legibility through Choice of Font and Color**

Tufte advocated the use of techniques aimed at improving legibility for the viewer. Serif fonts were recommended, since the eye easily discriminates between serif font letters. Tufte mentioned that varying shades of gray are a good way to present data within a graphic. Unlike color, which is not automatically set into a hierarchy by the viewer, our brain automatically orders shades of gray. When color is used in a graphic, a key should be provided, and the colors used should be of “quiet” tone, similar to those colors found in nature. Tufte advocated using the least effective difference when

choosing color and shading. Improved legibility promotes quick interpretation of the graphic by the viewer.

### **Core Value Six: Aim for High Data Density, and Eliminate Chartjunk**

Tufte did not believe that extraneous information or chartjunk belonged within good graphics. Tufte promoted the highest data density level that could be effectively represented on a graphic. The graphic vehicle should not add any content material or ink that was not necessary. For example, Tufte discussed line widths, and noted that the smallest width needed for visual perception, with the least amount of ink, was the most desirable. Anything that distracted the viewer from the data was deemed detrimental. Although moiré effects can reveal information about the cognitive development of our visual systems (Pinker, 1997), they are inappropriate and distracting to the viewer of graphics and should not be used.

While Tufte advocated non-redundant data ink in graphics, he made an exception with graphic depiction of continuous information. If a world map or a twenty-four hour train schedule was represented, Tufte encouraged the replication of some data on the ends of the graphic. This exception was made so that the viewer would have easy access to the data, and would not have to mentally piece together the information portrayed on the graphic extremities.

### **Core Value Seven: Best Graphic Displays Show Causal Relationships**

Tufte believed the graphics that showed causal relationships, or variation of Y with X, were better graphics. Causal graphics can present a tremendous amount of information that can be decoded because of the relationship between variables.

### **Core Value Eight: Reduce the Size of Graphics**

Tufte believed that graphics should be shrunk in order to take advantage of the resolution capabilities of the human eye. On average, Tufte believed graphics could be shrunk to 50% of their original size, while still retaining all the original information in easily discernible form for the viewer. This principle is in accordance with Tufte's other principle advocating high data density.

### **Core Value Nine: Landscape Formats are Preferred**

Tufte stated that viewers prefer horizontally stretched rather than vertically stretched graphics. This is because humans have practice viewing natural landscapes. Tufte also advocated the 1: 1.6 ratio as ideal for graphic dimensions. This ratio represents the Golden Rectangle ratio. Although Tufte admitted the rationale was dubious, he still promoted the ratio for graphic use on aesthetic grounds.

### **Core Value Ten: Escape Flatland**

Tufte stated that the best graphics escape beyond the limits of the flat or two-dimensional page. Great graphics present data in ways in which the viewer does not notice two-dimensional constraints. Tufte (1997) noted that communication between readers of an image and the designers of the image must take place in two dimensions; therefore "escaping this flatland is the essential task of envisioning information – for all the interesting worlds (physical, biological, imaginary, human) that we seek to understand are inevitably and happily multivariate in nature. Not flatlands" (p. 12).

### **Tufte's Graphic Opposition**

Not all graphic designers embrace Tufte's core values. Nigel Holmes is a commercially successful graphic designer who has had his creations published in *Time*

magazine and *The New York Times*. However, Holmes' graphics seem to break most of Tufte's principles for graphic excellence. Holmes (1984) promoted the use of "catchy" graphics. Whereas Tufte believed that design should never be seen as an alternative to data, Holmes proudly displayed graphics that incorporated heavy-handed design, omitted labeling, and used photographs as backdrops against which data were presented. The purpose of Holmes' creations does not appear to be the efficient display of data. Instead, Holmes advocated a design vehicle that would grab the viewer's attention. The data presented were often buried beneath or within the design, and the viewer would have great difficulty accessing real information. Holmes' 1985 book of graphic icons also obviously breaks many of Tufte's principles: The icons were drawn with a heavy-hand, and tended to be "catchy" rather than informative. Tufte used several of Holmes' graphics as examples of what *not* to do in his three-volume theory of graphic design. Tufte noted that when design takes over graphic presentation, and the data are lost within the vehicle, the graphic becomes a "duck" – a reference to 20th century stores and cafes shaped like objects.

### Effectiveness of Graphics

Since geology is a visual science, both Paivio's theory of dual coding, which promotes the use of visual as well as verbal instruction within the classroom, and Tufte's principles of graphic design, which provide a template for determination of superior graphic tools, are relevant in the geology classroom. However, there does not exist a large body of knowledge promoting or interpreting graphic use within the geology or earth science classroom. As noted earlier, ERIC and GeoRef searches turned up surprisingly few research studies on the use of graphics within the geoscience classroom. An investigation utilizing Dissertation Abstracts also yielded few citations with direct



relevance to this proposed research; however, five dissertations were located and acquired that have lateral impact on the topic of interest. These include Sgarbi's (1993) interpretation of an early illustrated manuscript, Hinline's (1993) research into the types of visual representations in earth sciences from 1863 through 1970, Mauzy's (1972) investigation into the graphic representation of abstract concepts, Parsons' (1965) investigation into the relationship of graphics to learning, and Weisberg's (1969) research into graphic advance organizers in earth science classrooms. These dissertation research studies, as well as geology and earth science education publications that investigate the visual aspect of the discipline, are discussed in the following sections.

### **Relationship between Text and Illustrations**

Sgarbi (1993) investigated a newly found illustrated version of Vitruvius' *De Architectura*, and discussed the effects of the graphics on the text. Whereas previous versions of *De Architectura* had no illustrations, the addition of illustrations to the version Sgarbi analyzed created "problems," since the manuscript was originally intended to be read and not visualized. However, Sgarbi (1993) noted "once the illustrations are introduced, they exercise such an attraction on the viewer that they free the interpretation from an adherence to the words, while in turn setting other limits on the possibilities of interpretation" (p. 5). Nonetheless, Sgarbi stated that the illustrations within this manuscript did not correspond with the text in a predictable and unambiguous manner.

### **Visual Representation in the Earth Sciences**

Hinline (1993) explored the types of visual representation through case studies in paleontology, geomorphology, and structural geology from 1863 through 1970. He characterized pictorial forms of this period into two types: "proxies" and "diagrams." Whereas a proxy was a representation of nature composed without much interpretation on

the part of the creator, a diagram offered inferences with which generalizations of nature could be made; some transformation of the raw visual data was made within the graphic. Hineline further hypothesized that proxies were “radically multivocal,” since there was only a pictorial representation that did not impose an interpretation. Diagrams, with their interpretations levied by the illustrator, were “reduced in multivocality, aiming for but perhaps never achieving univocality” (p. 385).

Paleontological illustrations were usually proxies, and their formats changed little from 1863 through 1970. In contrast, alteration of raw data occurred in both geomorphology and structural geology. Hineline researched the use of block diagrams by American geomorphologist William Morris Davis. These diagrams not only recorded the data, but interpreted landform evolution as well. Structural geology also incorporated diagrams rather than proxies, and Hineline discussed the “tectogene,” a theoretical diagram used to explain anomalies in gravity prior to the acceptance, in the 1960s, of the theory of plate tectonics.

### **Graphic Representation of Abstract Concepts**

Mauzy (1972) investigated the effects of graphical representation on imagery, learning, and retention. He randomly assigned 345 undergraduate students to five different groups to experience differing textual elaboration. Groups included a basic verbal group, a verbal group with extended verbal outlines, and three groups whose verbal texts were accessorized with varying degrees of visual representations. Following the learning session, Mauzy administered a posttest. Posttests were also administered as a two-week delayed retention test, a transfer test, and a questionnaire. Mauzy discovered that relevant mental images were positively associated with learning and retention of

abstract concepts. However, the experiment failed to adequately measure differences between the groups with structured and unstructured visual images.

### **Relationship of Graphic Representation to Learning**

Parsons (1965) conducted an experimental study at Montana State College in order to determine the effects of graphic representation on final learning, critical thinking, and reasoning. Professors of an education psychology course were chosen whose instructional abilities were similar, as measured by the final learning of past students. Students were assigned to either a control class or experimental class, with the only difference between the groups being the use of graphic representations in the experimental class. Both pretests and posttests were used to ascertain differences in students' performance based on the classroom presentation. The test results indicated a positive relationship between the use of graphic representations within the course and learning. However, no relationship was found for either graphic representations and critical thinking, or graphic representation and reasoning.

### **Advance Visual Organizers in Earth Science**

Ausubel's (1963) research inspired Weisberg's (1969) investigation into the effect of advance visual organizers in earth science. Ausubel stated that advance organizers facilitate learning and retention of verbal materials in a classroom; these organizers are presented verbally in a higher level of abstraction and inclusiveness than the material to be taught. Weisberg expanded Ausubel's research, and examined whether specific visual materials, such as maps and graphs, could serve as effective advance organizers for verbal material.

Eighth grade students in the Jersey City, NJ public school system were randomly chosen and assigned to groups. In these groups, students either received no verbal

advance organizers (control group), verbal advance organizers, or variable visual advance organizers. The unit of instruction was topography of the ocean floor.

ANOVAs of posttest scores revealed significant differences between the groups, with the greatest difference occurring between the groups receiving visual and verbal organizers. The greatest group mean difference occurred between the control group and the group receiving a map as the visual advance organizer. Weisberg noted that the map was pictorial, while a graph used as an advance organizer was more abstract. The group receiving the verbal organizer did not perform as well on the posttest, and Weisberg concluded that verbal advance organizers were inferior to visual organizers. Paivio and Csapo's (1973) research also supported this claim.

### **Visual Approaches in the Geoscience Classroom**

Few research articles on the use of graphics in geology and earth science education were located via ERIC and GeoRef database searches. However, there have been some research studies – though sparse in number – that discuss the use of graphics and visualization in the geoscience classroom. Although Ault (1994) noted that earth and space sciences have the distinctive characteristics of having scales, which in turn interact with the need to visualize, he further noted the absence of educational studies researching visualization in the earth science classroom. While the need for visualization exists in the classroom, the “how-to” articles written by classroom instructors “fill the void created by an absence of a research tradition explicating the relationship between geological reasoning and visuospatial aptitude” (Ault, 1994, p. 272).

Many of the publications addressing visual approaches to learning in the geology classroom confirmed Ault's statement. Jones (1979) discussed the construction of lunar eclipse diagrams and the representation of their data; however, he failed to include

guidelines or suggestions for incorporation of these diagrams in the earth science classroom. Brewer, Bolton, and Driese (1990) presented a new method for classifying sandstone. Although a ternary diagram was presented in the paper, the authors discounted a graphic component and stated, “no visual representation [such as a ternary diagram] is necessary to utilize the scheme” (Brewer, Bolton, & Driese, 1990, p. 343). Fortunately, some authors did acknowledge the importance of graphics in the geoscience classroom. Eves and Davis (1988) promoted the use of graphic depiction of the rock cycle; the authors declared the rock cycle was a unifying framework whose graphic depiction linked the processes and products discussed in the classroom. Sproull (1991) also advocated graphic use in the classroom through the use of the latest technological advances. He focused on a classroom activity utilizing computer-accessed topographic maps, and explored the relationships depicted within the graphic. Moseley (1992) and Hawley (1993) discussed the related topic of field diagrams. The articles, however, offered advice for improved production of field sketches by students; the articles did not focus on the visual importance of the diagrams, or the use of the diagrams by students. Moseley (1991) did note the importance of three-dimensional visualization in geology, and suggested the use of photographs in map interpretation exercises.

The latest recommendations from the Conference on the Revolution in Earth and Space Science Education (2001) may help promote new research into the use of graphics and visualization in the geology and earth science classrooms. The report from the conference clearly advocated the use of graphics with the proposal that “Student learning experiences should have a stronger emphasis on inquiry-based learning, use of visualization technologies and understanding Earth as a system” (Revolution in Earth and Space Science Education, n.d.). At all grade levels, students should be exposed to earth

science, and aided in this endeavor through expanded use of visualization technology in the classroom (Barstow & Geary, 2001). Interestingly, the use of visualization in the geology classroom may serve a general scientific literacy purpose: A study conducted by Orion, Ben-Chaim, and Kali (1997) showed that students' spatial-visualization ability was *significantly* improved after completion of their first geology course.

### History and Philosophy of Science in Science Teaching

The use of graphics is not the only technique that is advocated and has research support for improving the science classroom. As early as 1947, the history of science in the science classroom was promoted as a means to provide a better and richer understanding of the scientific field. Conant (1947), then President of Harvard University, stated that the history of science was “indispensable” in the science classroom. Conant further provided illustrative examples incorporating Lavoisier's and Boyle's experimentation within the history of science. Conant's advice concerning the history of science in the science classroom was, sadly, not well heeded: Duschl (1985) noted that the philosophy of science and the science curriculum had developed independently of one another for the previous 25 years. Duschl believed that incorporation of the philosophy of science and the history of science in the science classroom would greatly improve the teaching of science.

Matthews (1994) was a strong advocate of history of philosophy and science in the science classroom (HPSST). He stated that the scientific and philosophical histories could connect the science curriculum with social, cultural, and personal matters. The history of science and philosophy in the science curriculum could serve as humanizing agents. Several researchers have discussed the impact and benefits of the history of science within the science classroom.

## **Benefits Ascribed to a History of Science within the Science Classroom**

**A “Hook” for Students.** Matthews (1994) noted that students often claim science is just too boring. A history of science in the science classroom could make the curriculum more interesting for students. Furthermore, as noted by Wandersee and Roach (1998), the use of an interactive historical vignette (IHV) in the classroom can serve as a cognitive bridge for students.

**Integration of the Science Curriculum.** There have been many studies advocating the integration of subjects. Rieck (1999) noted that vertical integration (articulation across grade levels) as well as horizontal integration (articulation between subjects) was a desirable goal of education. The use of the history of science in the science classroom could serve to integrate the social, political, and cultural environments with scientific theory. Science did not develop in a vacuum, but was influenced by the historical environment in which it evolved. Suchting (1994) specifically noted the “interconnectedness” of things, and believed that the history of science could promote this idea of interconnectedness among other subject areas.

**Humanization of the Curriculum.** Science can be perceived as “cold” and “impersonal.” Jenkins (1989) advocated the use of history and philosophy in the science classroom as a way to “humanize” the science curriculum, and connect the scientific laws and theories to the people and environments in which the laws and theories developed. Jenkins believed that history of science in the science classroom could serve as a “bridge to the arts.” The history of science could provide richer insight, and counter what was perceived as scientism and dogmatism in scientific texts.

**Enhancement of Critical Thinking.** A goal of educators is to promote critical thinking among students. Matthews (1994) believed that critical thinking could be enhanced through the use of history of science and philosophy in the science classroom.

**Curriculum Planning.** A history of science can actually help educators plan the curriculum. Wandersee (1986) reported that an understanding of the history of science could often predict alternative conceptions that students bring into the classroom – the incorrect conceptions that are, according to Wandersee, Mintzes, and Novak (1994), resistant to change through traditional teaching methods. Wandersee noted that students' alternative conceptions often parallel (although not recapitulate) misconceptions held by scientists of the past. Wandersee believed that the history of science could help teachers predict students' alternative conceptions, and plan the curriculum accordingly. Good and Wandersee (1992) promoted the history of science in the science classroom by their development of a graduate course that taught educators on the use of history and philosophy of science in the classroom.

**Understanding the Nature of Science.** Matthews (1994) discussed the fact that science itself is intrinsically worthwhile, and contributes valuable knowledge. Bertrand Russell was quoted as stating that science offers a type of "Cosmic Piety," in which students are able to see that knowledge is judged valuable and correct irrespective of social or cultural influences (Matthews, 1994, p. xv). The history of science within the science classroom has the potential to teach students about the nature of scientific investigation. History of science can identify for students the various attributes of a scientific method, as well as expose why the method works well through replication of data, with nature as the final arbiter.



Anderson (2000) noted that there does seem to be a broad consensus as to what scientific knowledge should be imparted to students: most textbooks present virtually the same information, often in the same order of discussion. However, Anderson stated that the presentation of scientific information and theories was often perceived incorrectly as linear. Students may get the impression that convergent thought is the normal process in scientific endeavors. Anderson noted that this was false. Divergent thought must occur; otherwise, there would be precious little development of new hypotheses and understanding. Anderson believed that using the history of science in the science classroom could expose students to roles of divergent, as well as convergent, thought within the science curriculum.

Duschl (1994) also noted that the history of science was important in showing the restructuring and reorganization of scientific knowledge as new information became available. The history of science was an excellent tool for showing students the role that theories play within the development of scientific knowledge.

**Science Literacy.** Incorporation of the history and philosophy of science within the science classroom is a vehicle for promoting scientific literacy. Wang and Schmidt (2001) believed students should be aware of the historical, cultural, and political connections of scientific knowledge. They proposed that incorporation of history of science in the science classroom was a means of achieving science literacy. However, science should not be taught as a “rhetoric of conclusions” (Schwab, 1962).

**Understanding Current Educational Debates.** Matthews (1994) further noted that an understanding of the history and philosophy of science was necessary for educators to understand the current educational debates. The history of science exposes the value and promises of the scientific method, as well as its limitations. Since science

is not only a product, but a process as well, the history of science is needed in the classroom so that students can gain a better understanding of the process of science, or the “way science works.” Some researchers have promoted the organization of the scientific curriculum around sociological issues. For example, Kelly, Carlson, and Cunningham (1993) discussed sociological concerns in the teaching of science. The history of science lends understanding to these debates, even if educators do not, for example, personally ascribe to the postmodern perspective of teaching science.

### **What is Needed in the Classroom?**

According to Matthews (1994), science educators need to utilize three things for the effective teaching of science. Educators need the knowledge within their subject area, and educators need a teaching theory around which to organize their instruction. Finally, Matthews believed teachers should incorporate the history and philosophy of science within the science classroom. Although science is both a process of justifying knowledge and a process of discovering knowledge, students seldom are introduced to the discovery of knowledge, or “how we know” in science (Duschl, 1990). Incorporation of the history and philosophy of science in the classroom could make the change of theory within a discipline evident to students; thereby avoiding what Duschl has termed “final form science.” The history of science could be integrated into the entire science curriculum, or it could simply be added into an existing curriculum. Matthews noted that a curriculum change alone would not be sufficient to achieve positive effects from the history of science in the classroom; teachers would also need instruction on how to utilize the history within their classrooms.

Solomon (1989) discussed the use of historical debates as a method for incorporating the history of science within the classroom. Wandersee and Roach (1998)

reported another method to incorporate history of science in the classroom, the Interactive Historical Vignette (IHV).

### **Opposition to HPSST in the Classroom**

In the early 1970s, Martin Klein opposed the incorporation of history in the science classroom because the history presented to students was, out of necessity, partial and selective. Klein (1972) argued that this selective approach “is almost inevitably bad history” (p. 13), and believed that the very different natures of science and history preempted a symbiotic mesh. Matthews (1994) affirmed that on many occasions only a partial history was selected for inclusion in textbooks; the history chosen for inclusion was usually the version that supported the scientists’ eventual published results. This history did not accurately portray the controversies involved in scientific advance, and falsely showed a linearity of the field. Andersen (2000) also noted this problem in scientific textbooks. In other cases, the history actually included in science textbooks was pseudo- or quasi-history. Whitaker (1979) believed that this history arose as an expression of logical order within a text, and therefore within a classroom. Furthermore, a logical order is convenient for the teacher.

Matthews (1994) still believed some history was better than no history, and noted that history was not the only addition that brought “intellectual schizophrenia” to the science classroom (p.77). Science-Technology-Society (STS), for example, included moral and political issues within the classroom. In addition, Matthews believed that science is not impeded by history, and since the history used in the science classroom is for pedagogical purposes, it should not be judged by the same criteria as history written by the historian.

## The Golden Age of Geology

The historical age of focus for this research study was identified as the time period starting with Hutton's first published paper, 1788, through the end of the Golden Age of Geology, 1840. Sollas (1905) originally identified the "Golden Age of Geology" with the period of Buckland. This was probably because Buckland not only represented the geological sciences at Oxford, but also influenced many other geologists of the time. Buckland was a minister in the Church of England and initially a staunch catastrophist. He believed that "diluvium" deposits – obviously different from the alluvium deposited from rivers – were remnants of an ancient flood. Other practicing geologists of the time included Buckland's best friend Conybeare, Sedgwick at Cambridge, and Phillips in Dublin. Sollas further noted that Murchison, another prominent geologist, studied fieldwork under Buckland. Lyell was not only Buckland's pupil, but also his protégée inducted into the Geological Society of London. Sollas identified Agassiz as coadjutor; however, it was Agassiz who eventually disproved Buckland's diluvium hypothesis with his glacial observations and speculations on previous ice ages.

Sollas may not have intended for his invented term, "Golden Age of Geology," to be officially adopted; however Woodward (1911) soon quoted it when writing a history of geology, and added the names of De la Beche, von Buch, Boué, Elie de Beaumont, and Omalius d'Halloy to the list of Buckland's distinguished contemporaries. Woodward also expanded and further delineated this early period, and described it as the "Great Masters of Geology." This period, which included Sollas' Golden Age of Geology, was characterized by "strenuous field-work and by many grand discoveries in various parts of Europe and America" (Woodward, 1911, p. 75). The Great Masters period was specified as the years from 1820 to 1840. This period was also seen to follow what Zittel referred

to as the “Heroic Age of Geology,” a period extending from 1790 to 1820 (Woodward, 1907). It was in the Heroic Age of Geology that the relatively new geological science had its modern beginnings.

Sheets-Pyenson (1982) also used the Golden Age of Geology to identify the older generation of geologists, born near the beginning of the 19th century; she included Lyell, Sedgwick, Buckland, Murchison and De la Beche. Sheets-Pyenson also noted this Golden Age generation was separated from the younger generation of geologists born in the 1830s and 1840s, a geological generation whose ranks included Geikie, Sollas, and Judd. Therefore, a combination of the definitions and adoptions of Sollas, Woodward, and Sheets-Pyenson yields a specific age of geology in which geological giants were making great progress in the discipline. Although this age included the careers of many geologists whose publications create non-delineated boundaries, Woodward’s specification of 1820 through 1840 as a Great Masters period serves to demarcate the end of the Golden Age of Geology as 1840.

### **Early Geologists**

Amateurs, primarily, characterized this early period of modern geology. Hutton’s training was as a physician, Lyell’s as a barrister. The early Geological Society of London was comprised of members who were of sufficient social standing or independent means that geological interests could occupy their leisure time. Eventually in England there were positions available for full-time scientists within teaching institutions, museums, botanical gardens, the British Geological Survey, and the British Museum; however, Sheets-Pyenson (1982) noted that “the quickened rate of professionalization following the creation of the British geological survey [*sic*] induced

stresses and strains, particularly among institutions that had been created and directed by amateurs” (p. 186).

The earliest practitioners in the modern geological field, therefore, were those whose social standing precluded their admittance into the prestigious geological societies. Practicing geologists like William Smith, the creator of the first geological map of England, were noticeably absent among the membership list of the Geology Society of London. Sheets-Pyenson (1985) further identified another group of scientists: those who practiced geology in the field without any training at all, and who were not associated with Britain’s mining industries.

## **Publications**

As the geological field progressed, Sheets-Pyenson (1985) noted that geological periodicals became popular instruments to inform a growing literate population. These periodicals began to appear in the 1820s, when, as Sheets-Pyenson stated, mechanized printing presses were starting to increase publication output. It also appears that illustrations became important in this forum, and periodicals included “woodcuts, line engravings, or colour plates, ostensibly in order to increase the intelligibility of their presentation of scientific material” (Sheets-Pyenson, 1985, p. 552). Sheets-Pyenson further commented

As one reviewer noted, the popular author ‘must teach by illustrations that are a species of representation of what actually occurs, and impress the mind with livelier ideas than the mere abstractions of reason can convey’. Referring to the explanatory power of diagrams, one periodical insisted that ‘one square inch of wood is worth a page of letter press.’ (p. 552).

This time of increased illustrations in publications was also the time during which the great geologists of the Golden Age were active. Woodward (1907) noted that Berger

introduced, in a memoir, pictorial geological coast-sections drawn by Conybeare and Buckland. It was none other than Henry T. De la Beche who followed this style with signal success.

### Implications of Literature Research

Through the literature research into the Theory of Human Constructivism, Paivio's dual coding theory, Tufte's theory of graphic design, assorted studies that explored aspects of graphics in texts and the classroom, the History of Science and Philosophy in Science Teaching, and historical inquiry into the Golden Age of Geology, strong support is found for the investigation of the graphic innovations of Henry T. De la Beche and their ensuing implications for modern geology education. Tufte's theory of graphic design provides a template through which to gauge the quality of De la Beche's early illustrations, while the Theory of Human Constructivism and Paivio's dual coding theory lend guidelines for successful incorporation of De la Beche's graphics in the modern classroom. The History and Philosophy of Science in Science Teaching further supports the inclusion of historical graphics in the geology classroom as a vehicle to humanize science, promote science literacy, understand the nature of science, and enhance critical thinking. Research conducted on the relationship between graphics and learning showed a positive correlation; yet this is an under-researched and under-published topic in geology education. Therefore, an analysis of Henry T. De la Beche's unique visual approach to the emerging field of geology, and the subsequent implications for the modern classroom, is an investigation that has the potential to contribute in a substantial way to visual geology education.

Because the research involved not only an historical investigation into early geologic graphics, particularly those of Henry T. De la Beche, but also an evaluation of

the graphics and their potential for productive inclusion in the modern geology classroom, several research techniques were involved in this study. The methods included traditional historical research, as well as qualitative and quantitative analyses. The methodology is discussed in Chapter 3.



## Chapter 3: Methods

This research study differs from most academic degree studies in that it involves historical research, analysis of graphics exposed during the research, and interpretation of De la Beche's graphic innovations for relevance to the modern geology classroom. Best and Kahn (1993) readily admitted, "It is apparent that historical research is difficult and demanding. The gathering of historical evidence requires long hours of careful examination . . . Good historical studies are not often attempted for the purpose of meeting academic degree requirements" (p. 101). These authors noted that historical research was difficult since objects of study could not be viewed in isolation, but must be investigated within the interactions and institutions of their times; Best and Kahn agreed, however, that literature reviews for research were essentially basic historical research, and therefore some historical research was conducted by most researchers.

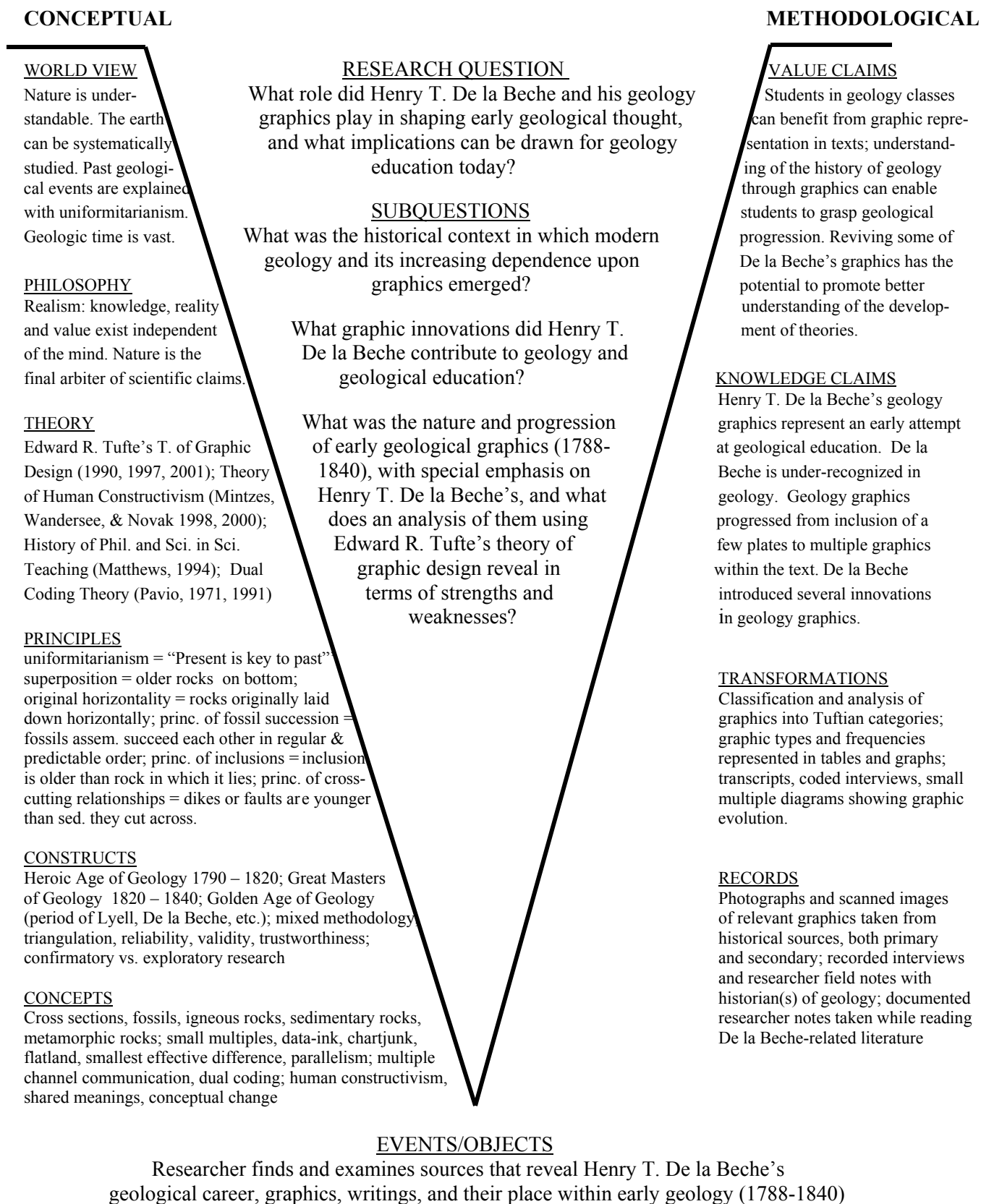
Criticisms that have been levied on historical research in education include the difficulty the researcher faces when generalizing on the basis of past events, the dependence on the reported observations of others, the lack of control – or missing parts – of the investigation, and the open system in which history operates (Best & Kahn, 1993). However, Best and Kahn argued that scientific qualities can characterize historical research: The historical researcher delineates a problem, forms a hypothesis, gathers and analyzes data, tests whether the hypotheses are consistent with the evidence, and formulates conclusions or generalizations from the study. The researcher also has access to data sources from different vantage points; principles of probability may be employed in the study, and the research may take the form of either qualitative or quantitative analysis. Although the historical researcher cannot control all variables of the study, this is often a characteristic of behavioral research as well.

Historical research into the graphics of Henry T. De la Beche, as well as investigation into the implications of these graphics for the modern geology classroom, was conducted through the use of a scientific method. The research plan was organized using Gowin's (1981) Vee heuristic, which is based upon five questions that need to be answered in order for a researcher to understand the structure of the scientific work. These questions include the telling question, the key concepts, the methods, the knowledge claims, and the value claims. The Vee arranges the conceptual and theoretical items of the research on one side, and the methodological items of the research on the other. The Vee is focused upon the events or objects that are investigated in order to answer the questions of focus, and the questions of the study are clearly delineated in the middle. Figure 25 presents the Vee for this research study, and the items of the Vee are discussed in depth in the next section.

### Delimiting the Problem: Gowin's Research Vee

The principle research question for this investigation is the determination of the role Henry T. De la Beche and his geology graphics played in shaping early geological thought, and the resulting implications for geology education today. Subquestions that contributed to this study include an investigation into the historical context during which geology and its increasing dependence upon graphics emerged, determination of the graphic innovations of Henry T. De la Beche within the fields of geology and geology education, and verification of the nature and progression of early geologic graphics, especially those of De la Beche. The age of focus for this study is the period from 1788 through 1840; the first published paper of Hutton that revealed the concept of uniformitarianism determined the beginning boundary, and the conclusion of the Golden Age of Geology determined the concluding boundary. The graphics that emerged during

Figure 25: Gowin's Vee Diagram of Research



the period of early modern geology were analyzed in terms of Tufte's (1990, 1997, 2001) principles of graphic design; strengths and weaknesses of these early geologic graphs were revealed. Implications of De la Beche's graphics and incorporation into the classroom were ascertained through the Theory of Human Constructivism (Mintzes, Wandersee, & Novak, 1998, 2001), Paivio's (1971, 1991) dual coding theory, and the History and Philosophy of Science in Science Teaching (Matthews, 1994).

The events and objects that were explored in this study were those sources that revealed Henry T. De la Beche's geological career, his graphics, his writings, and their place within early modern geology (1788-1840). De la Beche's publications, texts, letters, and notebooks, as well as resources discussing De la Beche and his contributions, were utilized during this research investigation.

### **Gowin's Vee: The Conceptual Domain**

The left side of Gowin's Vee represents the conceptual or thinking side of research, and includes the ideas that must be understood before the research commences (Mintzes & Novak, 2000). Mintzes and Novak (2000) noted that the conceptual domain represents prior knowledge, and it is this prior knowledge that affects the questions asked, the objects and events chosen for study, and ultimately the knowledge and value claims asserted.

**Concepts.** Concepts that figured prominently into this research study included basic geological terms such as fossils, the remains or traces of past life. The three rock types also figured into this study: igneous rocks (rocks formed from the cooling of magma or lava), sedimentary rocks (rocks formed from either cementation and compaction of sediments, or direct precipitation), and metamorphic rocks (rocks altered from pre-existing rocks by heat, pressure, and/or chemically active fluids). Cross

sections, one of the basic visual illustrative forms in geology, are those representations showing the layers of rocks and sediments from a vertical perspective.

Tuftian (1990, 1997, 2001) concepts were also involved in this inquiry. Small multiples are a graphic vehicle in which several small illustrations are sequenced over time, similar to movie frames. They are considered an efficient way to show multivariate change over time, since the viewer only has to interpret the graphic vehicle once in order to access all the data. Parallelism is similar to small multiples in that it shows more than one event, but the technique is aimed at providing different views of the same phenomenon; change over time is not necessarily a part of this graphic technique. Data-ink is the ink of the graphic design that is specifically designated for data representation; conversely, chartjunk refers to non-essential data-ink that erroneously takes up graphic space. Tufte believed, therefore, that data-ink should be levied in a manner so that the smallest effective difference was recorded. In his view, colors in an illustration need only to show difference, and lines utilized in the graphic's design need to be the smallest width that is possible to distinguish clearly. Flatlands to Tufte are the two-dimensional constraints of graphics. Good graphics should draw the reader beyond the limits of the page and "escape flatland" (Tufte, 1990).

Paivio's dual coding theory was also important to this study. Dual coding is the process by which different types of stimuli – in this case auditory and visual – are received and coded within independent systems of the brain. Although independent, the systems can interact with each other through referential processing. Multiple channel communication therefore exists when communication proceeds by more than one vehicle.

Human constructivism, the basis of the Novak's (1977) learning theory, identified the construction of the framework upon which knowledge is built. Students who have

well-organized and integrated frameworks are meaningful learners. The goal of education is shared meaning, or intersubjectivity; consensus exists as to what counts as knowledge. Conceptual change, or the restructuring of the learner's framework of knowledge, is facilitated through a learner's metacognition: knowledge, awareness, and control over learning (Gunstone & Mitchell, 1998).

**Constructs.** The constructs that affected this study include those describing different historical ages of geology. The Heroic Age of Geology, 1790-1820, was defined as that early period during which the modern concepts of geology emerged (Woodward, 1911). This period was followed by what Woodward termed the Great Masters of Geology, 1820-1840. The Great Masters of Geology incorporated Sollas' (1905) Golden Age of Geology, which was identified as that period during which Buckland and his colleagues – including Sedgwick, Lyell, and De la Beche – were active.

Many research constructs also applied to this research study. Tashakkori and Teddlie's (1998) construct of mixed methodology involves the integration of qualitative and quantitative methods across different phases of a research study. Their basis for delineating qualitative from quantitative research was the research design; exploratory research utilized a basic qualitative paradigm, while confirmatory research utilized a basic quantitative paradigm. Validity – the degree to which the investigator records what he or she intends to record – and reliability – the degree to which the results are reproducible – are two important issues in research studies. These two terms are often replaced with the concept of trustworthiness in a qualitative study. Trustworthiness, as defined by Lincoln and Guba (1985), is the degree to which the research is worthwhile and persuasive. The concept of triangulation can be utilized to ensure trustworthiness; this involves the practice of using more than one method for data collection. Denzin

(1978) believed that multiple data sources would improve the quality of the research endeavor. Traditional qualitative means for triangulation include member checking, peer debriefing, thick description, and prolonged observation. However, Bogdan and Biklen (1998) argued against the use of the term as confusing.

**Principles.** The principles that informed this study include the principle of uniformitarianism as originally proposed by Hutton. Uniformitarianism states that processes that operate today also operated in the earth's past, at the same rate and the same magnitude. The principle of uniformitarianism can be simply stated, "the present is the key to the past."

The other principles with relevance to this research are all principles used with relative age dating techniques. There are six principles that are considered necessary for relative age dating: the principle of superposition (older rock layers are on the bottom); the principle of lateral continuity (rock layers continue in all directions until they eventually "pinch out"); the principle of original horizontality (rock layers are originally deposited horizontally); the principle of inclusions (inclusions in a rock layer must be older than the rock layer); the principle of cross-cutting relationships (igneous intrusions or faults cutting across rock bodies are younger than the rock bodies); and the principle of fossil succession (regular assemblages of fossils succeed themselves in a regular and predictable order). The principle of fossil succession was introduced by William Smith, and formed the basis for his geologic map of England.

**Theory.** The theories that played a role in this research project are the Theory of Human Constructivism (Mintzes, Wandersee, & Novak, 1998, 2000), Paivio's (1971, 1991) dual coding theory, Edward R. Tufte's (1990, 1997, 2001) theory of graphic design, and the History and Philosophy of Science in Science Teaching (Matthews,

1994). All of these theories have been previously discussed in the Review of Literature in Chapter 2.

**Philosophy.** My philosophy in this investigation is a form of “modified realism.” I believe that there is an external, knowable world that exists independently of the observer. Reality and value also exist independently of the mind, and nature is the final arbiter of scientific claims.

**World View.** The worldview that exists, and which I adopt, is that nature is understandable. Knowledge can be acquired through the systematic study of the earth. The principle of uniformitarianism is the most reasonable conduit through which the current geomorphology of the earth can be explained. As a result of uniformitarianism, we must also accept an old earth; the earth is, in fact, 4.6 billion years old.

### **Gowin’s Vee: The Methodological Domain**

The right side of the Vee diagram is the methodological or “doing” side of the diagram. Here, the research that needs to be done in order to answer the focus question is specified. Records, the tangible artifacts of the investigation, code information about the event or object being studied.

**Records.** The records of this study consist of digital photographs and scanned images of relevant graphics in early geologic texts. Sources for these graphics are both primary and secondary. Hand-written and computer-typed notes were also taken during investigation of De la Beche-related literature. Interviews with pertinent history of geology authorities were recorded and transcribed. Field notes taken during these interviews were also recorded and transcribed.

**Transformations.** Once data were collected, the classification and analysis of graphics into Tufian categories proceeded. The graphic types and frequencies were



represented in tables and graphs, while transcripts of interviews were coded and summarized. Small multiple diagrams were created, showing the evolution of graphics within the age of focus. A modified timeline representing Henry T. De la Beche's graphic achievements was also produced.

**Knowledge Claims.** During the age of focus, geology graphics progressed from inclusion of a few plates of graphics after the text to incorporation of several graphics within the text. During this period, Henry T. De la Beche introduced several innovations in geology graphics. It was believed that this research study would show that Henry T. De la Beche's geology graphics represented an early attempt at geology education. Although De la Beche added much to the field of geology, he is under recognized today for his achievements and contributions.

**Value Claims.** Students in introductory geology classes can benefit from graphic representation in texts, and an incorporation of the history of geology within the classroom through graphics will enable students to grasp certain geological progressions. In particular, reviving some of Henry T. De la Beche's graphics within the geology classroom has the potential to promote better understanding of the development of theories important within the discipline.

### Paradigm of Investigation

In the past, educational research was characterized by the use of monomethods – either a qualitative or quantitative approach was used in research, but the two approaches were rarely mixed. Tashakkori and Teddlie (1998) stated the development of mixed *methods* followed. In mixed methods, qualitative and quantitative methods are used in a research phase. However, the authors proposed their new paradigm: mixed models. In mixed models, qualitative and quantitative methods are combined across all phases of

research. Experimental design, data collection, and data inference and analysis utilize both qualitative and quantitative approaches.

Historically, the quantitative method used deductive logic in which thought processes move from general to specific. In the quantitative method, internal validity is a prime concern. Although there are different methods for data analysis (or statistical analysis) within the quantitative paradigm, there is general agreement among quantitative researchers about these methods. Statistical techniques can be descriptive (such as measures of central tendency, relative standing, and association among variables), or inferential (such as t-tests and z-tests). Quantitative research, or confirmatory research, includes the use of one or more experimental variables, a controlled research setting, and the use of hypothesis.

Qualitative research, according to Tashakkori and Teddlie (1998) is based on a constructivist philosophy. Inductive reasoning is used in the qualitative method, with thought processes proceeding from the specific to the general. Unlike quantitative research, the qualitative researcher is most concerned with the external validity of the study. Lincoln and Guba (1985) described the qualitative researcher's concern with external validity and proposed new terminology – including transferability, confirmability, and dependability. These terms have become standardized in the qualitative research literature.

Qualitative researchers also have differences of opinion as to the format of qualitative research. Creswell (1998) discussed five qualitative traditions. He identified the case study, phenomenology, ethnography, biography, and grounded theory (as promoted by Glaser and Strauss, 1967) as the dominant traditions in qualitative research. Lincoln and Guba (2000) also discussed philosophical bases for the different qualitative

paradigms, as well as narrative approaches and data collection. Although the different qualitative traditions have variations that make them unique, there are several general characteristics of qualitative research (Tashakkori & Teddlie, 1998). Qualitative research is exploratory. It utilizes no directing hypothesis, and does not incorporate experimental variables. The setting is natural. Qualitative researchers do not place priority on numerical data, but focus instead on descriptive data.

### **Tashakkori and Teddlie's Proposal of Mixed Methodology**

Tashakkori and Teddlie (1998) acknowledged there were researchers in both the qualitative and quantitative camps who did not believe that these methods should ever be mixed. However, Tashakkori and Teddlie discussed their rationale for using both qualitative and quantitative methods in a single research study. The authors noted that both methods were funded, cited, and influenced politics. More importantly, both methods answered “how” and “why” questions. Tashakkori and Teddlie believed that the inclusion of both methods in a research study forced the researcher to utilize both inductive and deductive logic, which is similar to natural thought processes that occur in a normal research cycle. Furthermore, Tashakkori and Teddlie noted that few research studies were actually either a pure quantitative or a pure qualitative study. Most research did incorporate elements of both paradigms. The qualitative and quantitative paradigms did not represent a dichotomy, but a continuum of research positions.

Tashakkori and Teddlie advanced their compatibility thesis from a pragmatist position. Their philosophy acknowledged an external world, but also a world that could not be fully known. Whereas Guba and Lincoln (1994) believed that the actual paradigm was of greatest importance, Tashakkori and Teddlie (1998) stated that the *research question*, not the method or the paradigm, was of greatest importance in research.

Tashakkori and Teddlie (1998) advocated the continued use of triangulation within their new models as descriptive of multiple sources; the researchers believed that the use of a monomethod was a threat to the validity of a study. However, Tashakkori and Teddlie also believed that the MAXMINCON principle, as discussed by Kerlinger (1986), was still applicable in a mixed model study. MAXMINCON, historically a quantitative tool to ensure validity, represents maximizing the experimental variance, minimizing the error variance, and controlling the extraneous variance.

Some researchers have expressed opposition to the use of both qualitative and quantitative methods in a research study. Bogdan and Biklen (1998) stated that a researcher, especially a novice researcher, should not try to employ both techniques in one study. The resulting research, according to Bogdan and Biklen, would not meet the criteria for excellence in either the qualitative or quantitative paradigm. Creswell (1994) also opposed the use of mixed methods. Creswell noted that mixed method studies were too expensive, too time-consuming, and contained too much data to succinctly report.

I agree with Tashakkori and Teddlie that research studies often include both qualitative and quantitative elements, and very few research studies rely on a pure monomethod. The researchers' ideas on mixed methodology are applicable to my own dissertation research: My research focus has oscillated between confirmatory and exploratory. Therefore, I incorporated elements of both qualitative and quantitative paradigms in my research plan, and I utilized inductive thought processes as well as deductive thought processes.

My research employed the technique that Tashakkori and Teddlie (1998) referred to as parallel mixed methods. In parallel mixed methods, both qualitative and

quantitative designs are used simultaneously, as opposed to using sequential qualitative-quantitative, or quantitative-qualitative methodologies.

## Research Design

From the pilot study in the fall 2001, Henry T. De la Beche was identified as a focus of my dissertation research (Appendix A). An application for exemption from Louisiana State University's Institutional Review Board was subsequently filed and returned (Appendix B). Within the research investigation, both exploratory and confirmatory research strategies were used in order to ascertain De la Beche's contributions to the geological community, as well as potential contributions in the geoscience classroom. The possible contributions of De la Beche were explored, seeking confirmation of his importance through his works. A stylized flow chart depicting the research benchmarks is presented in Figure 26.

## Sources of Data

Tashakkori and Teddlie (1998) noted that the inclusion of both clinical and formulaic data added to the richness of the research study. They identified observations, questionnaires, interviews, and archival research as possible means through which to collect data. Following Tashakkori and Teddlie's suggestion to include different types of data in my research study, several sources were utilized, including historical texts, archival material, interviews, and a field trip to the Bath, England area for first-hand exposure to one of the regions studied and mapped by early geologists, including Henry T. De la Beche, William Conybeare, and William Smith.

Both primary and secondary sources of data were used for this research project. Primary sources include the letters, drawings, sketches, and field notebooks within the Henry T. De la Beche archives in the National Museum of Wales, the British Geological

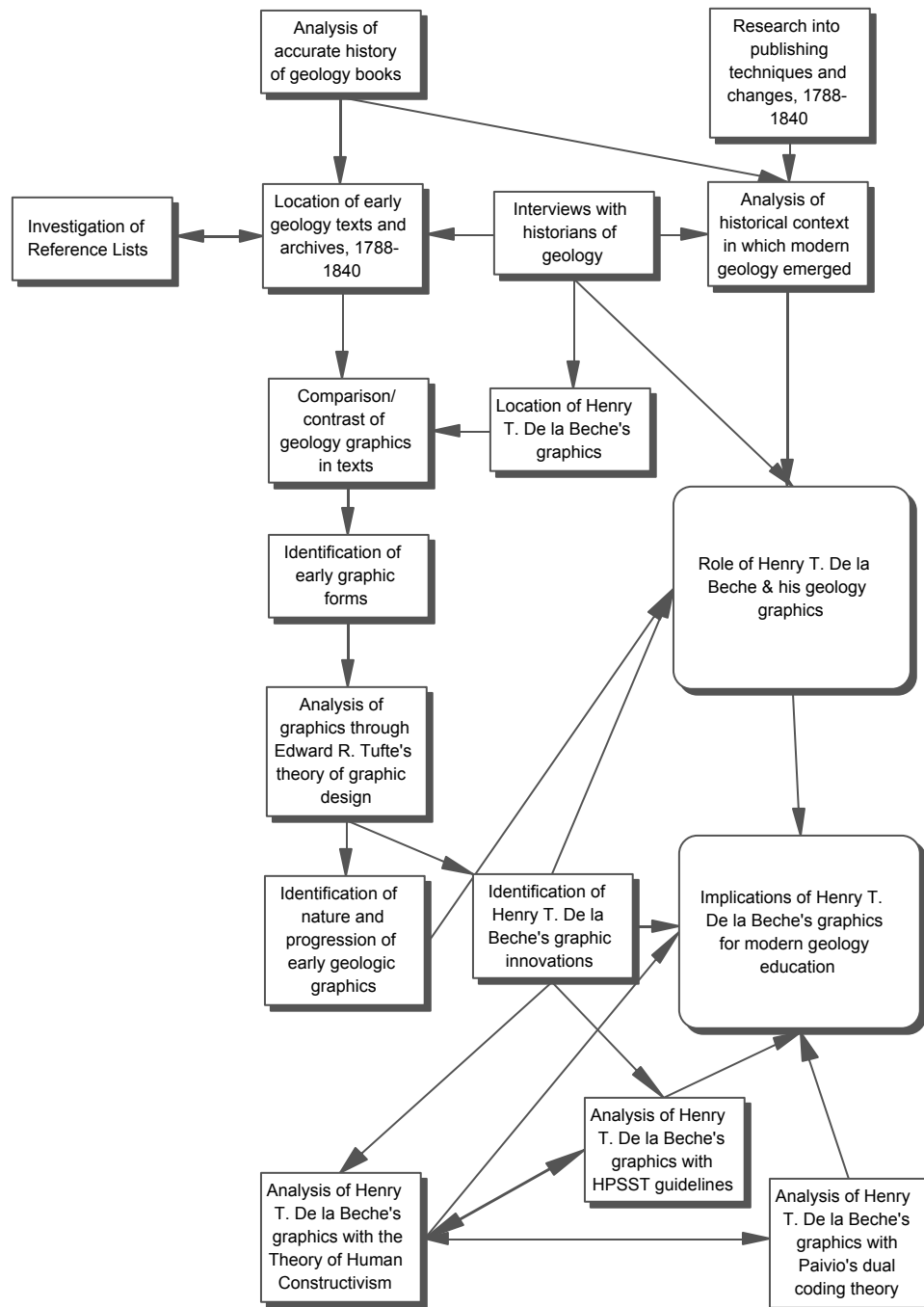


Figure 26: Stylized flow chart depicting the major benchmarks in the research investigation.

Survey, the British Museum, the British Library, and the Geological Society of London. Because this study involves the illustrations of De la Beche's geology texts, original texts (as opposed to facsimile versions) by De la Beche and other geologists in the age of focus are also considered primary data sources.

Secondary data sources were utilized as well. History of geology texts, history of printing texts, facsimile texts, biographical accounts of early geologists, and data retrieved from interviews with historians of geology and experts are some of the secondary sources of data integrated into this research.

**Books.** Original and facsimile texts published during the early modern period of geology played an important role in the pilot study (Appendix A). Geology texts published during the age of focus (1788-1840) were identified in the pilot study, and investigated as to their incorporation of illustrations. Although a sampling of texts by various geologists in the age of focus was studied, the published books of Henry T. De la Beche were explored thoroughly to ascertain the numbers, types, and information portrayed within the included graphics. Louisiana State University's Middleton Library and Hill Memorial Library (which houses the Rare Book and McIlhenny Collections), and interlibrary loan services provided some of the identified texts. Texts that could not be acquired through these facilities and services were investigated in the United Kingdom at the Geological Society of London, the British Library, the National Museum of Wales, and the British Geological Survey. Figure 27 maps the sites of the various facilities and localities visited during the research trip to the United Kingdom. Letters of introduction from Dr. James Wandersee, my major professor and Professor of Curriculum and Instruction, Science Education at Louisiana State University; Dr. Brian Lock, Professor and Head of the Department of Geology at the University of Louisiana at Lafayette; and Ms. Elaine Smyth, Curator of Special Collections at Louisiana State University, gained my admittance into these library facilities, which are closed to the general public (Appendix C). Before the research trip to the United Kingdom, a list of books to be investigated was compiled (Appendix D). Books and publications on the list were those



Figure 27: Map identifying locations visited during the United Kingdom research trip. (The map is modified from <http://www.ukguide.org/ukmap.html> )

general geology texts published between 1788 and 1840 that were referenced in history of geology texts (Geikie, 1905; Woodward, 1907, 1911), or discovered through electronic searches of online library collections. Other books and publications not on this original research list were later added to the investigation on the recommendation of historians of geology, archivists, and geology librarians. All publications of Henry T. De la Beche that had not been investigated in the pilot study and subsequent research were also added to the book and publication list for investigation in the United Kingdom. These publications were identified through Sharpe and McCartney's (1998) catalog of the De la Beche



archives, which listed the totality of De la Beche publications. Although many De la Beche publications fell outside the Golden Age of Geology, they were still researched in order to ascertain whether any changes in De la Beche's focus or pattern of illustrations had occurred after 1840.

**Archival Documents.** The De la Beche Collection constitutes the major part of the archive collection of the Department of Geology in the National Museum of Wales in Cardiff. It includes over 2,000 items of correspondence, travel journals, copies of official minutes, and family photographs (Sharpe & McCartney, 1998). Some of the original sketches for De la Beche's impressive 1830 book, *Sections and Views, Illustrative of Geological Phænomena*, are located in this collection, as well as letters from De la Beche's colleague, William Buckland. The curator of the collection is Mr. Tom Sharpe, who offered much assistance in this research project.

A list of the archival documents with importance to this study was made prior to the trip to Wales (Appendix E). Mr. Sharpe informed me before my visit to that he was able to provide photographs of the images within the archives, as well as transcripts of the documents (Tom Sharpe, personal communication, March 19, 2002).

Both the British Geological Survey and the Geological Society of London also have archival collections that include primary documents authored by De la Beche. Lists of documents to investigate and analyze at these institutions were also compiled (Appendix E). Mr. Graham McKenna, chief librarian of the British Geological Survey, offered much assistance in the identification of documents relevant to this research study. Archival material was also viewed at the British Museum.

**Evaluation of Documents.** The trustworthiness of historical data, or historical evidence, is determined through the processes of external and internal criticism.

External criticism establishes the legitimacy of the data; this should not be a primary concern in this investigation since documents held in De la Beche archives in the National Museum of Wales, as well as archives in the British Museum, the Geological Society of London, and the British Geological Survey have been previously authenticated. Internal criticism, the evaluation of accuracy or worth of the documents, was carefully conducted; the opinions of curators and historians of geology were sought to confirm my evaluations of archival material.

**Interviews.** Stephen Jay Gould (1998) identified Dr. Martin Rudwick as the world's most noted historian of geology. Dr. Brian Lock, Head of the Department of Geology at University of Louisiana at Lafayette and former student of Dr. Rudwick's at Cambridge University, introduced me to Dr. Rudwick through electronic mail. Dr. Rudwick kindly agreed to an interview, and offered his insights and advice during our three-hour conversation in Ely, England. In addition to interviewing Dr. Rudwick during my research trip to the United Kingdom, I was also fortunate enough to interview Mr. Tom Sharpe, the curator of paleontology and archives in the Department of Geology at the National Museum in Wales, and Mr. Graham McKenna, chief librarian at the British Geological Survey. Appendix C presents letters of support for this research project from Dr. Rudwick and Mr. Sharpe.

The interview guidelines I used were those open interview guidelines discussed by Patton (1990). This protocol combines a conversational approach with an interview guide; a certain number of basic questions were predetermined prior to the interview (Appendix F). However, the interviewing process maintained a flexibility that allowed probing questions for in-depth investigation of certain topics. Appendix B discusses the

interviewing technique more fully, and includes a consent form as part of Louisiana State University's Internal Review Board document.

**Field Experience.** While in the United Kingdom, I joined the History of Geology Group of the Geological Society of London, and attended the July 13-14, 2002 field trip to the Bath, England area. The trip, led by Dr. John Fuller and Dr. Hugh Torrens, probed the industrial basis of stratigraphy from 1719 through 1813. Several sites were visited that were important in John Strachey's, and later William Smith's, geologic interpretations of the countryside. A modified itinerary for this field trip is presented in Appendix G.

### **Sampling Techniques**

During the fall 2001, a pilot study was conducted to determine the feasibility of the dissertation project (Appendix A). Although the earliest presumption was that Playfair's book, *Illustrations of the Huttonian Theory of the Earth*, would include several pictures and graphics, research was refocused when a facsimile copy did not confirm this hypothesis; no graphics were included in the text. The remainder of the semester was spent in an exploratory mode: Many early geology texts from 1788 through 1840 were procured and investigated as to the use – or nonuse – of graphics in each.

For the pilot study, the sampling technique can be characterized as purposive and convenient. Geology texts published from 1788 through 1840 that were located in Louisiana State University's Middleton Library were analyzed, along with several texts in the McIlhenny and Rare Book collections at Hill Memorial Library. The sampling strategy also employed the snowball technique: As early geological texts were read and analyzed, other texts of interest would often be referenced. History of geology texts also identified several texts within the period of early modern geology; referenced books were

then requested through interlibrary loan services (ILL). The sampling became as exhaustive as possible considering the availability of the books from libraries participating in ILL services.

This exploratory research led to the “discovery” of a forgotten geologist: Henry T. De la Beche, who was then identified as a focus of the research study. De la Beche emerged as a prolific geological writer during the period in question. The sampling techniques that were utilized for the remainder of the research were both exploratory and confirmatory in their foundation.

Sequential sampling was used for geologic texts within the age of focus. Sampling techniques identified early geologic texts and their included graphics, and sampling continued until a high level of certainty was obtained. This level of certainty was reached when catalog searches failed to turn up new geology texts within the age of focus, and when historians of geology and other experts recognized only those geology texts that had already been included in the study. Sampling concluded, therefore, when saturation was reached, and no new texts were identified.

Confirmatory – and exploratory – research was conducted through an exhaustive sampling of Henry T. De la Beche’s publications. Since this investigation centered on the graphic genre of De la Beche, as many as possible of the geology graphics he produced were acquired and sampled in order to determine his approach to the visual geologic discourse. The only articles and books authored by De la Beche that were not researched were those that were not available from the libraries and museums visited: three non-English publications on Swiss lakes, a German translation of *Researches in Theoretical Geology*, a French translation of *Sections and Views*, and the original 1855 version of the *Catalogue* for the Museum of Practical Geology, copies of which could not

be located in either the Geological Society of London library or the British Geological Survey library.

## **Analysis**

As early geologic texts were reviewed, a preliminary analysis of the graphics was simultaneously conducted. Notes were taken on the number and type of graphics included in the text, and the use of direct labeling, color, keys, and scales. Texts acquired from Middleton Library and interlibrary loan services allowed photocopying of documents; important graphics were scanned for further interpretation as needed. The Geological Society of London and the British Geological Survey allowed digital images of texts held in their collection; photographs were taken of all of the De la Beche graphics. Representative samples of graphics from other texts were also digitally photographed. These photographs were used for additional in-depth study as needed. The types, numbers, and characteristics of graphics in early texts established natural categories for further analysis.

Graphic analysis proceeded through both qualitative and quantitative methods. Early graphics were compared with each other in order to expose similarities and differences. The guideline for analysis emerged from Edward R. Tufte's theory of graphic design (1990, 1997, 2001).

**Quantitative Analyses.** Categories were initially created for proxies or pictorial representations, labeled proxies, inferred graphics, small multiples, and relational graphics. The authors of the texts in which the graphics appeared, as well as the publication years, numbers of graphics, and types of graphic additions were assembled in tabular form. Publication years, number of illustrations, and graphic density were analyzed through measures of central tendency and measures of variability. Ranges for

the graphic types within the age of focus were computed, as well as the mean, median, and mode for the number of graphics and the graphic density within publications. Correlation analysis was conducted to ascertain whether a relationship existed between publication year and the number of included illustrations. A scatterplot was also created to reflect these data.

De la Beche's illustrations were more thoroughly examined. The vehicle of publication for De la Beche – whether periodical, book, or government document – was investigated; the number of each type of publication per year was plotted and evaluated. The graphic density of each De la Beche text published within the age of focus was calculated and plotted in a bar graph. Each of the texts was examined as to the percentage of proxy or pictorial images, labeled proxies, inferred graphics, mathematical or relational graphics, and small multiples. Graphic analysis was also conducted for the types of geological graphics in De la Beche texts, whether landscapes, maps, sections, fossils, or diagrams.

**Qualitative Analysis.** The illustrations of early geologic texts were also qualitatively analyzed using other properties of Tufte's principles of graphic design. Parameters for analyzing graphics included data density, chartjunk, and multivariate properties of graphics. The qualitative analysis of early geologic texts was transformed into a small multiple graphic that depicted the changing nature of geology illustrations over time.

The illustrations of Henry T. De la Beche were subjected to thorough analysis. Qualitative analysis of De la Beche's graphics was used to identify patterns and trends. These patterns were then employed in the creation of a unique timeline of De la Beche's graphic progression. As qualitative analysis of De la Beche's graphics progressed, the

illustrations were placed into categories, which effectively quantified the data. These quantitative data were then analyzed; data density, chartjunk, and the multivariate nature of De la Beche texts were graphically depicted. Finally, the ratio of graphic modifications in the form of color, alphabet labels, and direct labels was also computed and represented. This method is similar to Tashakorri and Teddlie's (1998) mixed model design Type I: qualitative data are quantified, and statistically analyzed.

**Interviews.** Interviews were conducted with Dr. Martin Rudwick, noted historian of geology, Mr. Tom Sharpe, curator of the De la Beche Collection in the National Museum of Wales, and Mr. Graham McKenna, chief librarian of the British Geological Survey. These interviews were recorded, and field notes were taken. The verbal data were then transcribed, yielding 59 pages of single-spaced text, and 13 pages of field notes. Transcriptions of field notes are presented in Appendix H. The transcripts, as well as the field notes, were then analyzed using Chi's (1997) verbal analysis as a guideline. Chi's method is manifested in eight concrete steps, which begin after the initial collection and transcription of verbal data. The first of Chi's steps is the reduction of protocols. This can be accomplished by either random sampling, choosing a subset based on a noncontent criterion, or through the use of preliminary coding of the entire set. The use of preliminary coding was found to be the most efficient method of reduction in this research study. The interviews were initially reduced into preliminary categories, which included background information of the period of focus, De la Beche's status, De la Beche's contributions to geology, and specific innovative visual techniques in geology. Eventually, each of these categories was formally coded and classified.

Once protocols were reduced, they were then segmented to identify the unit of analysis. The size of the segment, the size of the segments' relation to the questions, the

data characteristics, and the determination of whether segmentation was necessary were the issues that were considered in this step. In general, the segment size utilized for the transcripts of this research can be considered a “macro” unit, since the larger unit was determined to encapsulate knowledge and inferences at a more appropriate level. The macro segment also revealed the reasoning behind each inference, which corresponded suitably with the interview questions asked.

Step three of Chi’s (1997) verbal analysis guide involved the development of a formal coding scheme, which is presented in Appendix I. However, not all elements of the coding scheme were applicable to every interview. Step four concerned the categorization of the macro segments through use of the coding scheme. The coded data were then depicted graphically in order to effectively present the data, and to make identification of patterns easier. The graphic depiction method used was the concept map (Novak & Gowin, 1984; Wandersee, 2002), since the use of macro and micro concept maps effectively organizes the data under a superordinate concept, and depicts relationships among the data through the use of links and cross-links. Henry T. De la Beche was chosen as the superordinate concept of the macro map, with historical background, early modern geology, and contributions as the concepts of the next tier. Micro concept maps were then constructed with early modern geology, contributions of Henry T. De la Beche, and contributions of other geologists in the Golden Age of Geology. Appendix J presents the interview analysis concept maps. These concept maps made the sixth step of Chi’s method – the identification of patterns – much easier. The seventh step was the interpretation of the pattern and determination of the validity of the interpretation. Dr. Rudwick, Mr. Sharpe, and Mr. McKenna were all offered the opportunity to verify the interpretation of the patterns observed; the validity of the



interpretation was also reviewed against the published primary and secondary sources used in this investigation. Although Chi (1997) admitted that the eighth step, repetition, might seem “masochistic,” it is often necessary to repeat the entire verbal analysis. This was done for specific themes when there were disagreements between my interpretations and the individual who was interviewed.

### **Control of Error**

In data collection, error should be minimized to the greatest degree possible. Tashakkori and Teddlie (1998) advocated the use of both traditional qualitative and quantitative procedures to minimize error and increase the validity of a research study. Validity is addressed on two fronts: internal validity and external validity.

Internal validity, or the credibility of the research, focuses on whether the data and results of the research can be trusted. Internal validity in this study was partially maximized by avoiding selection bias. Sequential sampling of early geologic texts proceeded until saturation occurred, while the publications of De la Beche were exhaustively sampled. The measuring devices and rubrics used – the categories created for graphic types and graphical excellence based on the principles of Tufte (1990, 1997, 2001) – accurately measured what they were supposed to measure if they provide replicable results. Therefore, peer debriefing was used to verify the research conclusions; other researchers familiar with Tufte’s theory of graphic excellence independently validated the accuracy and consistency of the rubrics and the analysis. Geology historians also provided information as to their perceptions of Henry T. De la Beche’s part in the age of focus. This hopefully reduced any potential bias I might have toward De la Beche’s graphics.

Bias was also addressed and alleviated through the use of thick description of graphics analyzed. The interviews were of sufficient length to ensure that prolonged engagement reduced the possibility of error. The interview protocol also included member checking: All people interviewed had the opportunity to view the transcript and coded analysis of their interviews, and suggest corrections if necessary.

The multiple sources of data and methods utilized further reduced possible error. The use of multiple methods, referred to as triangulation by qualitative researchers, is useful since the weaknesses of one method hopefully will be offset by another method. Tashakkori and Teddlie (1998) believed that the use of both qualitative and quantitative methods was a use of triangulation, and increased the validity of the investigation.

The ability of the researcher to apply the conclusions of the research to other settings constitutes external validity. Historically, quantitative researchers referred to external validity as “generalizability” of research, while qualitative researchers referred to “transferability.” Tashakkori and Teddlie (1998) discussed two modes of generalizability, based upon inductive or deductive thought processes. Both modes of generalizability were used in this study. In the inductive mode, data were gathered from specific geology texts, graphics were analyzed, and then generalized as a common theme evolved through the research. The generalization then switched to a deductive mode, whereby the general abstraction that emerged was applied to specific situations, in this case, introductory geoscience classrooms. In order to achieve external validity, the sample – the historical documents investigated – must be such that the results are truly representative of the population. This is not always an easy task for historical research, as will be discussed in the next section.

## Interpretation and Generalization of Historical Data

Best and Kahn (1993) reported that even historians disagreed as to whether or not generalizations from historical research were possible, and if validity was possible when applying historical research conclusions to other times and places. Aydelotte (1963) stated the obvious: It was never possible to have final proof for any historical generalization. However, even though finality of knowledge is impossible, this is also the case for natural sciences. Gottschalk (1965) believed that historical synthesis had a wider applicability beyond the data set that it was built upon, and “the historian should not . . . hesitate to make his [*sic*] own generalizations” (p. 256). Finley (1963) clarified that to *understand* was, in fact, to *generalize*. Through every explanation one or more generalizations is implied.

Therefore, although generalization of historical conclusions may be difficult, I believe that it is possible to make accurate generalizations through analysis of historical data. The researcher must simply take exceptional care to sample efficiently, and use scientific procedures when interpreting and concluding. It was through the thorough analysis of early modern geologic texts that a general theme of De la Beche’s graphic use emerged, and it was through the deductive application of this theme that the value of De la Beche’s graphics for the modern geology classroom was ascertained. Although the Golden Age of Geology has been adopted as the time period during which the progression of early geology graphics was investigated, this construct was simply the means to an end, and not an end in itself. The Golden Age of Geology is used to focus the historical investigation of the emergence of geologic illustrations, but the ultimate goal of this research is the improvement of visual geology education.

## Chapter 4: Results and Discussion

### Historical Context of the Emergence of Modern Geology

The research question guiding this study is the determination of the role played by Henry T. De la Beche and his geology graphics in shaping geological thought, and what implications can be drawn for geology education today. In order to concentrate the investigation to answer this question, three subquestions were identified. These subquestions focus on the historical context in which modern geology evolved, the graphic innovations contributed by Henry T. De la Beche to geology and geoscience education, and the nature and progression of early geology graphics in the age of focus (1788-1840). Since the subquestions contribute significantly toward the discussion and results of the main research question, data will be presented and discussed for each subquestion within this and the following two chapters. The results and discussion from all of the subquestions will be subsequently utilized for a discussion of the primary research question in Chapter 7. This current chapter concentrates upon the first subquestion, and ascertains the historical context, from 1788 through 1840, in which modern geology evolved as a science.

#### Identification of Historical Factors

It is fairly obvious that no person, organization, or vocation arises and develops independently of the surrounding social, cultural, and technical factors. Therefore, the environment in which modern geology evolved influenced the practice of the science; the science, in turn, influenced the environment. In any discussion of the factors affecting a person, group, or event, it is impossible to thoroughly document and reveal all the interacting components that impinge on the growth and evolution. This is especially difficult in an historical situation, removed by many years from the modern analysis. Not

only are interviews with original observers impossible, but also accounts written by eyewitnesses may reflect the very customs, traditions, and culture that are to be analyzed. In addition, it is easier to discuss an historical context by focusing upon different factors into which the context may be segmented and characterized. Such categories, by their very nature, divide the history artificially into neat packets that never existed. The categories we devise are dependent as well. Various interactions occur across the parameters of the divisions, making identification of all the interactions impossible. In an analysis of historical context, a researcher cannot avoid being selective. However, it is this selectivity that allows the “big picture” to be effectively ascertained.

Modern geology, the beginning of which is defined in most current geology texts as the proposal of the Huttonian theory, has undoubtedly been influenced by many factors outside the science. Secondary texts that were examined in the pilot study (Appendix A) seemed to indicate that both religious concerns and the social stratification of England exerted pressure on the developing science. The primary textbooks examined in the pilot study exhibited differences in numbers and types of illustration use within the period of focus: Whereas early geology books of the early 1800s tended to be sparsely illustrated, graphics were practically prolific by the 1830s. This observation indicated further research was needed into technological advances of the period; in particular, innovations in printing may have affected graphic use.

The ways in which social, religious, and technological factors influenced the young science of geology were investigated through primary and secondary sources, including both texts and interviews. These outside forces, combined with the very nature of the fledgling science, its contributors, and their contributions helped to mold the direction of growth for geology. In order to effectively discuss the historical context into

which modern geology came into being, the social and religious factors, the technological innovations, and the nature of the science of geology within the Golden Age of Geology will be presented and discussed. Figure 28 presents a concept map that outlines the basic features of these historical factors. Although some issues involved in the evolution of early modern geology in continental Europe will be presented, the majority of the discussion will focus on the setting into which geology developed in Great Britain, since the Geological Society of London provided the backdrop for many of the major geological discussions of the period of focus, and many of the leading figures in early modern geology – including Henry T. De la Beche – were British.

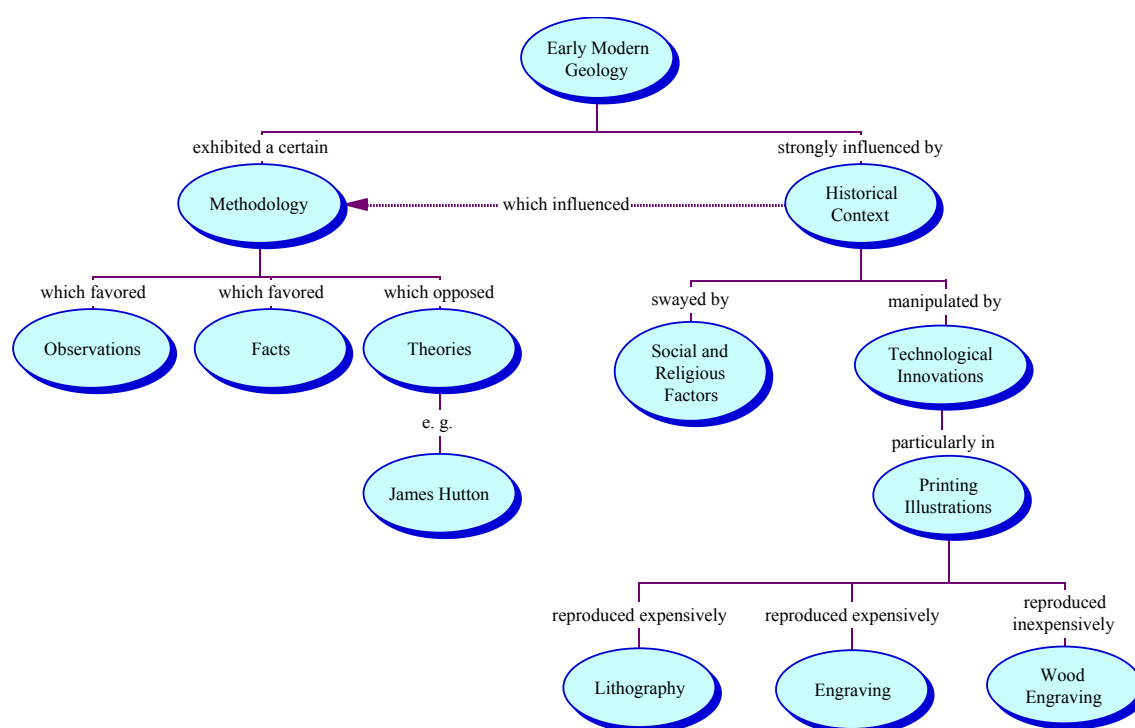


Figure 28: A macro concept map reveals some of the basic factors influencing early modern geology. This map was composed from the interview with Dr. Martin Rudwick on July 3, 2002.

### Social and Religious Influences, 1788-1840

During the 52 years of the age of focus, many different philosophies affected and influenced the society and culture in which modern geology arose. The Romanticism

movement, in which nature and sentimentality were valued above all else, influenced European culture from approximately 1775 through 1830. By the 1830s, however, the idealist philosophy of Romanticism seems to have been replaced by the realist philosophy of Bacon. Nonetheless, Allen (1976) believed that the unifying strands of social influence in 19th century Great Britain could be categorized broadly as Victorian, and that they sprang from a combination of emotional and religious factors that he identified as non-sectarian Evangelicalism. This dominant social force had its roots in the late 1700s as a resurgence of the Puritanical mindset. Allen (1976) questioned the sincerity of the movement, though: He believed that the reinterpretation that led to Victorianism was nothing more than emotional re-labeling, and the feigned emotion that resulted became “sentimentality, the mere sop to fashion of those who could not or would not commit themselves in the fuller way required – a debased substitute which by reason of its very shallowness was able to travel much faster and much farther” (p. 76).

The British also relished the self-control and industriousness of the Puritanical forebears. It was expected that a person could sit for hours in a stilted position on a hard wooden chair, listening reverently to a speaker on natural history, a society’s presidential address, or a reading of literature. This seriousness of purpose and degree of application were typified by the voluminous texts that were produced during the age of focus. These texts were judged on the author’s effort, which translated into books’ sheer mass and volume (Allen, 1976). Content was only a secondary consideration.

Fortunately, Romanticism and sentimentality did have the positive effect of focusing people’s attention upon nature. The self-control and industriousness that were so valued also helped to initiate rigorous natural science investigations, the facts and results of which were eventually published in a plethora of texts and periodicals. The

renewed interest in natural science had the additional benefit of being interpreted as a divine mission: Any involvement with nature – even in endless tasks of categorization – was viewed as respectful and praising to God and His creations on earth. The result, therefore, was that natural history was considered fashionable by the 1830s. Natural history had a further advantage of producing a raised “social consciousness.” Through natural history, the lower social classes might be enlightened and educated.

One of the advantages of natural science was that the research involved fieldwork within the earth’s “natural laboratory.” Romantic ideals stressed the investigation within natural settings, away from the isolated laboratories; travel and fieldwork became a metaphor for education and experience (Porter, 1977). Gentlemen of leisure also found travel and fieldwork a pleasant change from the duties and demands of their social lives (Rudwick, 1988). Natural science provided a domain in which stilted social behavior could be cast aside. The scientific pastime was also perceived as masculine, and perhaps owed its success to the perception that it “fostered noble speculation; it made a man seem forward-looking and economically constructive” (Allen, 1976, p. 59).

**Social Stratification in the Sciences.** Natural history, and in particular geology, grew in popularity within the age of focus. However, the field was by no means homogeneous; different groups of people were involved in the science at different levels, and to different extents. The social classes to which the individuals belonged largely determined this participation, as well as the general perception of their contributions to the emerging science.

By the 1830s, there was a well-developed tier system of geological participants. At the top of the geological pecking order were such important gentlemen of science as Charles Lyell and Adam Sedgwick, the first professor of geology at Cambridge. It



appears that the upper ranks of geology took its members from either the gentlemen of means, or university chairs. Accomplished gentlemen of science, such as Charles Darwin, were next in geological stature. Professional men such as mine managers and land surveyors followed, with the general population forming the bottom tier of the scientific participants. However, the scriptural geologists – those people who were scriptural literalists and chose to conform the earth's data to fit into the Biblical account – were effectively kept out of the science (Rudwick, 1988).

It is important to note that this tiered system describes the status of the science by the 1830s. However, early in the age of focus, there essentially were only two types of geological participants: the gentlemen of means who theorized about the science within the confines of the geological societies, and the lower class participants who earned their living in the field, either as miners or surveyors. Thus, the gentlemen of geology used their *intellect* to theorize about the developing science, whereas the lower classes of participants performed a *physical* service.

Within the period of focus, important changes began to occur within the social stratification of geology. The range for participation in the science broadened with increased employment opportunities, including the need for independent collectors, university professors, surveyors, and mining professionals. Perhaps the most notable change was the development of a professional class within the ranks, a sort of middle class of geology. Porter (1997) believed the evolution of these upper and lower social groups of geology – primarily serving regional economic interests – was important in the growth of geology; he identified groups as the professional surveyors and mining consultants, and the other affluent members of the “liberal professions, including professional scientists, usually living in the metropolis” (p. 136). By the very nature of

their professions, the surveyors and consultants were removed from the theoretical scientific development that usually occurred in the major cities. Professionals did not have the luxury of leisure time that the upper level of theorizing geologists enjoyed, either. This time shortage made it difficult for them to read the developing literature and to make a contribution. Furthermore, the geological texts were expensive, and were therefore inaccessible to those professionals who could have best used them (Allen, 1976). According to Porter (1977), the results were dated theoretical bases within the work of professionals. Adding to the tensions of the group was the fact that the surveyors and consultants were not united as a group: Since they often competed against each other for jobs, their cooperation was “sporadic and unstable” (Porter, 1977, p.137).

Although different groups existed within geology, it is important to remember that these groups were not totally isolated from each other. There was contact between the collectors, the professionals, and the gentlemen theorists. Porter (1977) noted, however, that the contact was of a “slightly tense form, involving deference, patronage, and suspicion” (p. 143). However, he believed that the diversity and competition provided the stimuli and an ideal environment for the rapid growth of British geology between 1790 and 1830.

It should also be noted that interaction was actively encouraged to some extent: In order to acquire knowledge for the growing field of geology, a booklet of questions was developed by Greenough, the first president of the Geological Society of London, and Arthur Aiken, chemist. The book was distributed not only to the members of the society but to many non-members as well. Allen (1976) believed that this resulted in the first network research initiated by a permanent, organized body. The consequence was

an organized system of observers, which incorporated various social levels; local information trickled into the Geological Society of London.

Although geology did attract a variety of people at various social levels, those with the most influence on the emerging science appear to have been the socially elite. Geology attracted many distinctive men of personal weight and influence to its ranks (Allen, 1976). The elite's attention and interest in geology was further reflected at the undergraduate level at the university. While the field trips of the botanists at Cambridge proceeded on foot, barge, or stagecoach, the students of geology enjoyed visits to the field with Sedgwick on horseback. Given the expense of maintaining a horse, and the rare occurrence that undergraduates traveled in this fashion, Allen (1976) believed this was an additional indication of the more elevated social status of the science of geology.

However, the science was not well-established within the university system of England during the age of focus. There were only two professors of geology in England: Buckland at Oxford, and Sedgwick at Cambridge. In this sense, the United Kingdom was far behind the continental European countries, which had established geology as a science in universities long before. European countries further utilized the knowledge gained from geological investigations within their mining industries.

All in all, the “official” scientific circles – usually exemplified by society membership - were rather small (Rudwick, 1988). Membership requirements for society membership, whether the Paris Société Géologique or the Geological Society of London, were relatively nondescript: Men must have an interest in the science and an “appropriately attested social respectability” (Rudwick, 1988, p. 257). Therefore, although the variety of professions was diverse within the societies – including book publishers, ministers, chemists, and professors – a social standard was still in force. This

existed despite the Geological Society of London's claim of integration between the working geologists and the theorizing gentlemen: The society was from the beginning, a society for gentlemen amateurs (Rudwick, 1963; Porter, 1977). It should be no surprise, then, that surveyor William Smith, the creator of the first geological map of England and Wales and now sometimes credited as the "Father of English Geology," was denied membership, even after he received the Geological Society's Wollaston Medal of honor.

As previously mentioned, the gentlemen who speculated about the emerging geological science were not completely isolated from the local observers, collectors, and professionals. Other social classes were appropriately valued as excellent sources of information. However, the type of information gathered from those of lower social stature was limited. Whereas the people of lower social standing were allowed to *collect* natural objects, the *theorization* about such objects was viewed as entirely beyond their capabilities. Knell (2000) noted that most gentlemen of the science were not above gathering specimens, facts, or practical knowledge from the local observers; however the opinions of the local observers were not necessarily needed, or considered. The social difference between collectors in the field, versus collectors of specimens, also carried over into museums that housed the specimens. In general, specimens in museum collections were only mentioned when they involved benefaction (Knell, 2000). Indeed, as Price (1986) reported, although Mary Anning was a noted and respected collector of fossils in the 19th century, there was no mention of her name on the computer-generated list of donors, collectors, and venders of the specimens of the Sedgwick Museum at Cambridge. It was only through diligent detective work that Price managed to identify Anning-collected specimens. Ironically, the single object recorded as an Anning donation in five major English institutions is a small coprolite! (Torrens, 1995).

**Role of Women.** The elite theorizing geologists often overlooked or minimized Mary Anning's contributions to the growing field of geology. Although she was marginalized within the science because of her low social standing, she faced another barrier due to her gender. Unfortunately, her plight was not that unusual for women during the Golden Age of Geology: Women were excluded from universities, scientific societies, and career opportunities that were available to their male counterparts. In Europe, women were not formally admitted to universities until the late 1800s, and it was not until 1945 that the first female was allowed entrance into the prestigious Royal Society of London (Schiebinger, 1987). Likewise, the Geological Society of London did not allow women members until 1919, and it was not until 1927 that the first woman was professionally employed at the British Geological Survey (Burek, 2001). This lack of women in the early scientific community was apparently not even noteworthy to some sociologists investigating the origins of science: Schiebinger (1987) reported that, although participation in science was studied from angles of age, class, and religious affiliation, theorists did not even bother to analyze the female (non) participation in the field; no mention was made in important social analyses of science that the early composition of scientific societies was generally 100% male.

When women were allowed to attend scientific gatherings, they usually did so. Knell (2000) noted that women were admitted to the first meeting of the British Association in York in 1831, and they showed up in large numbers. However, these women were not participating in serious geological discussion: A distinction was made between the social evenings during which women were admitted, and the evenings for business, during which time women were barred. Therefore, direct participation by women in the sciences was considered unusual, although a few did break the barriers that

ostracized them. The exception to female non-participation, as noted by Knell (2000), was that a distinction was made between utilitarian participation in the field, and the theoretical and governing participation of the society. Although women were excluded from the elite business of the society, they were allowed to contribute as collectors. Females of higher social standing could also manage to participate in an indirect fashion through their marriage to scientists. Wives occasionally accompanied their husbands in the field, and some women, such as Charlotte Murchison and Mary Buckland, were actually quite skilled geological artists. Burek (2001) concurred that women *were* contributing in the emerging geological sciences, but were “hidden behind husbands, brothers, fathers and colleagues, forbidden by society to expose their ability and knowledge” (p. 111). While women were contributing to geology by supporting male relatives with their work, the scientific community did not usually acknowledge them.

Although Knell (2000, p. 91) stated that the field of geology was “undertaken by both men and women at all levels,” this seems to be in opposition to what is observed in correspondence and printed geological articles from the period. Knell was correct in noting that the participation of women in geology was certainly difficult to ascertain: Very few females are mentioned in conjunction with the development of early modern geology. If women actively participated in the science at *all* levels, it appears their participation was not adequately documented.

**Religious Influences.** Social influences effectively kept women in the margins of science, and contributed to the stratification of geological contributors based upon their social status. Another important cultural influence on geology between 1788 and 1840 was religion. As Knell (2000) noted, “religion gave geology an imperative” (p. 39). In geology, the moral and the useful were intertwined; geological pursuits could be

defended as investigations into the exploration of the wonders of the creation (Allen, 1976). Therefore, even collecting was sanctioned in the name of religion. Natural science investigation became the passion of many religious figures, including Conybeare and Buckland. The participation of the religious in geology had the added bonus that these men were able to move freely within a variety of social groups and settings: Since they were trusted, they had access to knowledge from a broad spectrum of the population (Knell, 2000).

Although the boundary between religion and science was not as defined as it is today, most geologists did accept certain beliefs about the nature of the earth as revealed through the science. By 1788, the beginning of the period of focus, the idea of an ancient age of the earth was almost universally accepted (Porter, 1977; Rudwick, personal communication, July 3, 2002). Perhaps as a result, scriptural geologists were seen as marginal to the science.

However, the emerging science of geology did not exclude religion. The Bible was used as a source of *human* historical text, “an ancient history on par with Roman history and Greek history” (Rudwick, personal communication, July 3, 2002). This was not necessarily in opposition to the geologists, who were trying to write a reliable history for the *earth* through the strata. Linking the textual evidence – the human history of the Bible – to the physical evidence – the earth history as revealed in the rocks – was a perfectly natural undertaking, and had nothing to do with the fundamentalism of the 20th century (Rudwick, personal communication, July 3, 2002). As a result, many imprecise boundaries existed between the sciences and religion, and the continuing debates created a prolonged war-like atmosphere in the 19th century (Porter, 1977). The debates were perhaps fueled by the fact that many geologists did not ascribe to one system of the other,

but incorporated beliefs of both the scientific and religious systems. For example, Rudwick (1988) noted that although Sedgwick dismissed scriptural geology, he did subscribe to the belief that geology reinforced natural theology, and organisms were the products of beneficent and intelligent design.

The influence of religious beliefs was furthered by the recent political turmoil as well. The French Revolution resulted in religious and political counter-revolutionary attitudes that served as a reminder to geologists of society's boundaries for acceptable earth science (Porter, 1977). Any theories or views within the sciences that seemed to counter the teachings of Christianity were objectionable. Therefore, the infusion of religion into geological texts added a certain measure of safety. Parkinson's (1804) frontispiece merged both the scientific and religious: While a fossil ammonite rests on the near shore, Noah's ark is also presented, beached in the distance. Rudwick (1992) that Parkinson's frontispiece may have been specifically designed to dismiss any suspicion that the book had subversive intentions. The frontispiece is presented in Figure 29.

Unfortunately, the impetus for the beginning of modern geology, Hutton's *Theory of the Earth*, was considered to be part of the subversive view. Porter (1977) pointed out that the conjuncture of Hutton's publication with the storming of the Bastille was on some accounts an "intellectual catastrophe." Indeed it was a catastrophe, or rather a series of catastrophes, which may have reconciled the science with the theological. The prominent French anatomist Georges Cuvier proposed catastrophism, in which a progression of geological catastrophes – the most recent being Noah's flood – were responsible for the landscape of the earth. The result of this hypothesis was that people "felt freed to study fossils without any tormenting pangs of conscience;" catastrophism





Figure 29: The frontispiece of Parkinson's 1804 text, fusing both scientific and religious elements.

became the central topic of discussion within geology in the 1820s and 1830s (Allen, 1976, p. 70).

The effect of interacting politics and religion in the age of focus supported an empiricist mode for the science of geology. This, however, was not necessarily a detriment to the emerging science. Porter (1977) believed the empirical mode was a formula for success, since “such extreme empiricism was invaluable in generating the self-sustaining nature of geological science in the early nineteenth century” (p. 131).

## **Technological Advances, 1788-1840**

Just as cultural influences helped to popularize the emerging science of geology, industrial and technological advances also served to promote the science. However, both Porter (1977) and Allen (1976) warned against overestimating the importance of industrialization on the emerging field of geology. Although excavations done in the name of industrial expansion obviously provided opportunities for fossil hunting and section investigation, Allen (1976) believed that not all interest in the emerging field arose because of monetary gain. There existed genuine curiosity in the field, which could then be applied in practical ways. Technological advances in industry no doubt affected geology, particularly in the coal mining industry as the need for fossil fuels increased. However, of more importance to this discussion are the technological advances in the printing industry, particularly advances in the reproduction of graphics that were developed in the age of focus.

**Printing Advances.** Since geology is a visual science, technological advances that promoted the inclusion of graphics in publications, and affected the quality of the illustrations, are important milestones in the development of geology. Indeed, Ivins (1953) stated that the story of graphic reproduction is not the story of art, but the story of the most powerful method of communication and its effects on western civilization. This is because science and technology need more than illustrations for their texts; science and technology require pictures that can be repeated exactly and accurately (Ivins, 1953). In his discussion of the emergence of a visual language for geology, Rudwick (1976) noted that graphics' usefulness was limited until technical inventions allowed mass reproduction of images. However, by approximately 1840, the technology supported

inclusion of illustrations to the extent that graphics became an essential part of the visual and verbal communication of the science of geology.

In the earliest years of the age of focus, the copper plate was the means of graphic reproduction. An expensive technique, it was reserved for only a few graphic inclusions. Although the copper engraving preserved fine lines of maps and drawings, Rudwick (1976) believed it was less successful as a tool for capturing landscapes and natural science specimens. The engravings also had to be printed separately from the text, usually on a different type of paper from the text. The graphic pages were then bound, and were usually placed at the beginning of the text or at the end. However, there do exist a few rare books that have a few plates interspersed within the text. Despite these disadvantages, as well as development and improvement of illustrative reproductive techniques during the age of focus, copper engraving continued in use until the middle of the 19th century.

According to Steinberg (1996), the turn of the 18th to the 19th centuries marked a decisive stage in the history of printing; printing took a sudden leap forward. Ivins (1953) also declared that with the 19th century, the “printed picture may be said to have come of age” (p. 93). Revolutions in processes were made not only in graphic reproduction, but in text reproduction as well, including advances in the covering and binding of printed sheets. Nonetheless, Steinberg (1996) enumerated three important advances in illustrative techniques that accompanied mass production of printed texts: lithography, steel engraving, and wood engraving.

The invention of lithography greatly affected the duplication of images in the natural sciences. The process was invented and perfected by Senefelder, who introduced it in 1804. Ivins (1953) believed Senefelder’s discovery did two remarkable things: It

freed the original artist from the reproductive engraver's interpretations since the lithograph and the artist's drawing were practically identical, and it allowed the public repeatable pictorial representations. Ivins (1953) noted that the "reign of second-hand visual information was drawing to its close" (p. 88). Certainly, graphics in books were not made by illustrators, but by copyists of their drawings, and this had a definite effect on the viewer. People were forced to rely on graphics for a visual portrayal if they had no first hand information. However, the graphics only gave the people of the 18th and 19th centuries the possibility to "only be reasonable, for it was utterly impossible for them to be right" (Ivins, 1953, p. 91). Ivins noted that it was impossible for the viewer to verify quantitative aspects of the graphic unless he or she traveled to the site; when this was done, the information depicted was never accurate. In particular, the sizes of the reproductions bore no relation to the sizes of the objects in nature. Lithography helped to improve this situation, because the middleman or translator was no longer required for the reproduction process (Ivins, 1953).

Although lithography allowed greater shading and detail to be expressed, it was slow to be adopted in natural science publications, partly because the first lithographs were rather crude (Rudwick, 1976). Lithography was not generally used for geology texts until the 1820s, although the first British text that incorporated lithographic images was published almost 20 years earlier (Clair, 1976). However, lithography provided a cheaper medium than engraving, and for geological purposes, it was a more effective medium (Rudwick, personal communication, July 3, 2002).

The substitution of steel for copper in engraving techniques next affected geological texts. Although the price of steel and copper engravings was similar, the resilience of the steel allowed more fine-detailed copies to be printed per plate (Rudwick,

1976). In addition, Steinberg (1996) noted that steel engraving offered a wider spectrum of tone than that which could be achieved through copper. What appears to have had the greatest impact on graphic inclusion, however, was the technique of wood engraving, commonly referred to as wood-cuts by the authors of the period. Thomas Bewick developed this technique, in which the end grain of very hard boxwood is carved, in the late 1700s. Although wood engraving eventually became the most influential illustrative reproductive technique until the advent of photography (Clair, 1976), it was slow to be implemented in the geological texts. Part of the reason may be that the technique could not come of age until it became more common, and therefore, less expensive (Ivins, 1953). Once the technique was widespread, its cost was not the only advantage it offered: Wood engraving also allowed the printing of illustrations within the text. No special press, paper, or binding was required, and the durability of the wood was such that it could make as many copies as the lead type of the text (Rudwick, personal communication, July 3, 2002).

One drawback of the technique, however, was its lack of fine detail in reproduction. Therefore, once wood engraving became available, it still was not the only technique utilized for the reproduction of illustrations. The advantages and disadvantages of each technique were considered when inserting an illustration: A wood engraving was adequate for spatial structure relationships and simple cross sections, while the subtleties of paleontology specimens would be better represented with lithography, or steel or copper engraving (Rudwick, personal communication, July 3, 2002). Another limiting factor in the use of wood engravings for illustrations was perhaps due to the attitude of the publishers; the catalyst for the change of numerous wood engraving inclusions might have been the commercial success of publisher Charles Knight's *Penny Magazine* in

1832, which was the first periodical to use widespread use of wood engravings (Clair, 1976; Rudwick, 1976).

Penny magazines were first started in the 1820s in the United States, and were then transported to England, and from England to the European continent (Steinberg, 1996). The success of these inexpensive periodicals, as well as inexpensive books, was fueled by the demand of the rising artisan class; the growth of industrialization and education made it possible for the less wealthy to acquire the printed page (Clair, 1976). Furthermore, the French and American Revolutions had stirred public interest in politics and society, and inexpensive periodicals were the means by which the people could track current events and remain informed.

Clair (1976) believed that book production reached a high standard between 1790 and 1830. With the appearance of the steam press and the subsequent reduction in printing costs, a new industrialized society eagerly purchased books and periodicals that sold for prices within their means. However, as a result of the mass mechanization of printing, Clair believed that quality became a second consideration to quantity, and the standards of printing declined, especially after 1840.

The process of color printing was not a factor during the age of focus. Although in 1838 Charles Knight patented a color printing process known as Patent Illuminated Printing, the technique was not utilized for the popular press until the 1840s. A decisive future revolution in graphic reproduction techniques, however, was the development of photographic techniques and reproductions. Interestingly, the photograph – the most accurate portrayal of an object – was considered by some as lowest on the scale for artistic value. Ivins (1953) noted that in the United States there was the general opinion that etching was more artistic than wood engraving, which was more artistic than wood

cutting, which was more artistic than lithography. Photography was the least artistic of the illustration reproduction processes. Since photographs furnished exact replicas, they were visual reports of objects, and not necessarily products of artistic expression.

### **Nature of the Science of Geology, 1788-1840**

Social and cultural factors, as well as technological achievements, influenced the emerging science of geology in the age of focus. Although it is impossible to completely analyze the science independently of the cultural and technological influences, there are still certain traits of geology – perhaps characteristics of the very nature of the science – that guided its development as it materialized into a modern scientific field. Whereas other scientific fields have long histories and were established in their practices by the late 18th century, geology was a comparatively new science. In fact, J. A. Luc had only introduced the word “geology” in 1778. He later remarked, “of all the sciences, the most extensive and the most complex is that which was termed geology, before it was entitled to the name” (Woodward, 1907, p. 1).

Geology began to distinguish itself as a science in the later 1790s, when, according to Porter (1977), the former aspects of the natural history of the earth were rejected as being too constrictive and obsolete. The science developed, therefore, from the collecting of fossils, to the understanding of fossils in relation to geologic strata, to the understanding of fossils within a broader context of the evolution of life on earth (Porter, 1977). The science grew rapidly. The definition of “geology” was absent in *Encyclopaedia Britannica* in 1797, but the science had sufficiently grown to warrant a long article by the fourth edition of 1810. Growing pains were still evident in 1810, however, and Greenough, then president of the Geological Society of London, reported

that standardized nomenclature was impossible with the present state of the science (Porter, 1977).

Although geology grew rapidly, it was still constrained by the previous demands on Britain during the 22 years of Napoleonic Wars, lasting until 1815 when Napoleon was banished from Europe (Knell, 2000). The culture of geology, according to Knell (2000), was “mature and complex in 1840, but only being born as a recognisable specialism in the years after the Napoleonic Wars” (p. 27). Sheets-Pyenson (1982) noted that the discipline had grown dramatically between 1790 and 1830, coinciding with the rapid transmission of information.

Great Britain did not necessarily support her geologists, however. Geology was maintained as a science in continental Europe long before it was in Great Britain, with Europe leading the professionalization of geology with national surveys, mining schools, and more university positions. Each European country had its own mining school, and future mine administrators were educated in a variety of scientific, as well as practical, skills (Rudwick, personal communication, July 3, 2002). Britain also paid her scientists poorly: According to Allen (1976), the nation had a repugnance to allocating national funds on any activity, regardless of the potential for future pay-off. Therefore, political maneuvering was necessary behind the scenes, and well-connected individuals worked to bring changes to the country. In this regard, Allen (1976) named Henry T. De la Beche as the “master ‘operator’ of the nineteenth-century scene, the worthy heir to the line of grand interventionists that descends from Sir Hans Sloane and Sir Joseph Banks” (p. 87).

**Role of Theories.** The science of geology experienced a shift in focus from its modern beginnings with Hutton’s theories of 1788 and 1795. Although Hutton proposed the unifying theories of uniformitarianism and the igneous origin of granite, the period



1790-1820, or Zittel's "Heroic Age of Geology," was marked as a period of transfer from speculation to observation (Knell, 2000). Most geologists within the age of focus valued observations and facts, and were cautious about theorizing. They were "reacting against early theories represented by Hutton particularly . . . the mega-theorizing, the large scale theorizing about the earth . . . a huge theoretical superstructure based sort of like a pyramid, situated on a rather tiny base" (Rudwick, personal communication, July 3, 2002). The founding members of the Geological Society of London endorsed rigorous collection of facts, and were skeptical of the proposed theories of the science (Rudwick, 1992). Rudwick believed that this suspicion of theories greatly influenced the young science of geology. The reluctance to theorize was generally carried to excess, and the result was that a systemized geology did not exist. The Geological Society of London's disavowal of theorizing also served to put the new science politically above suspicion (Rudwick, 1992).

Even if the elite geologists within the Geological Society of London tried to move away from grand theorizing, they still embraced the role of theory decidedly more than the working and professional classes of geologists. The new professionals – the surveyor and mine consultants – attacked the preoccupation with fossils, minerals and theories as ends in themselves, and tended to ignore analysis of landforms and processes (Porter, 1977). Porter further noted that these men championed the populist features of Baconianism, including the role of the practical worker in science and the dismissal of speculative theorizing. The elite geologists, however, did not necessarily hold these strict views. Even though Henry De la Beche acknowledged the immature state of geology and denounced the proposal of theories before sufficient observations were made, he still analyzed the rocks and formations within the context of past environments, and viewed

them as “muddy rivers & seas” (Knell, 2000, p. 280). De la Beche, in spite of his reservations about the specific thesis of Lyell’s *Principles of Geology*, did migrate toward Lyell’s central position towards science (Gillispie, 1959).

Therefore, the elite geologists differed from the practicing geologists, not just in their social classes, but also in their views on the role of geology. Very few people who possessed practical knowledge of the earth made contributions to the developing theories, and very few theories that were developed by the elite geologists were applicable to the professionals who worked with the earth (Porter, 1977).

**Move toward Specialization.** The tendency towards fact collection was not the only trend observed in the early modern science of geology: Porter (1977) noted that a significant characteristic of the founding members of the Geological Society of London was their tendency toward specialization. Although Porter admitted that specialization was a relative term, the founding figures in geology were more narrowly focused than the members of the elite societies of the previous generation. The move toward specialization was not only confined to geology, but to the other sciences as well. Gone were the polymaths of the 17th and 18th centuries; the intellectual began to concentrate on specific areas of knowledge. The new trend, perhaps even started with the founding of the Geological Society of London outside the Royal Society, continued with the founding of other specialty science groups. The origin of the Geological Society in 1807 established the independence of the emerging science, and undoubtedly contributed to the specialization – or the identity – of the field, at least among the elite group of gentlemen who became the first members. Periodicals began to reflect this focus on specialization as well.

As far as the specialization of geological careers, England was slower than its European counterparts. Henry De la Beche, as the first director general of the British Geological Survey, was the first Englishman of stature who actually made a career, and a living, from his practical geological skills. Although the foundations of the systematic study of fossils and minerals were advanced in continental Europe, it was some time before they were imported to England (Porter, 1977). Early in the age of focus, most of the geological participants were amateurs, but as the 19th century progressed, positions became available at teaching institutions, local natural history museums, botanical gardens, and national organizations like the British Geological Survey (Sheets-Pyenson, 1982). Sheets-Pyenson believed it was the founding of the British Geological Survey in 1835 that did the most to establish geology as an occupation: In addition to the surveyors in the field, the geological survey created positions for laboratory research, as well as staff members for the Museum of Practical Geology, the Mining Records Office, and the School of Mines. Positions also opened in North America, Australia, and British colonies around the world (Sheets-Pyenson, 1982). Both Flett (1937) and Bailey (1952) discussed the founding and history of the British Geological Survey in detail.

**Contributors and Competition.** It has already been noted that some contention existed between various groups of geologists during the age of focus. After all, these groups were separated by their social status, the nature of their participation in the science, and their views toward the importance of theories. Competition and rivalry also existed *within* the various groups as well. Since surveyors and mining professionals had to compete for job opportunities, they did not form a unified, supportive group. Likewise, controversy also followed the elite groups, and competition was further witnessed in the interactions between geologists of different countries. Knell (2000) noted the rivalry

between England and the European continent among the different levels in the science of geology, and stated it indicated the “enterprise culture which geology in Britain had become” (p. 30).

Competition was not necessarily viewed as detrimental to the science, however. Geological communities “encouraged a pervasive air of rivalry and jealousy” (Knell, 2000, p. 32). Whereas papers read at the Royal Society were received with silence and respect, this was not the case in the Geological Society of London. Discussions there might border on a good fight. Rudwick (1988) believed that the parliamentary seating arrangement facilitated and *encouraged* the quarrels, since it was “easier to have a good argument with a man facing you than with one in a row behind your back” (p. 253). The fighting was productive, as theories were constantly proposed, defended, tested, and modified through the challenges of contemporary geologists. Sollas (1905) observed that one of the greatest contributions of William Buckland to the science of geology was his modification of position on the Noachian deluge. Whereas Buckland initially was the most powerful advocate of the Great Flood theory, he reconsidered his position as new evidence was revealed; eventually he abandoned the theory altogether.

One battle in particular has been well documented: the controversy over what was eventually to become the Devonian System (Rudwick, 1979, 1985). From 1834 to 1840, the conflict was played out in the field and the Geological Society of London, with Henry De la Beche and Roderick Murchison the principal actors in the saga. Rudwick (1979) insightfully noted that differences in geologic reasoning contributed to the debate, as did personal animosities. Once De la Beche’s personal fortunes faltered, he was fortunate to become the first Director General of the British Geological Survey. However, since his livelihood depended upon his position, and his position was

dependent upon his competence as a field geologist, his reputation was important and vulnerable. Therefore, when President Greenough read a letter from De la Beche to the Geological Society of London, the attack by Murchison on De la Beche's interpretation – and his geological skills – was a personal affront. Rudwick (1979) reported that De la Beche was angry that his competence as a geologist had been questioned in so public an arena, and summarized the conflict as one between fact and theory. Both Murchison and De la Beche gathered supporters for their positions, and the conflict escalated into a personal feud as well as a geological one. By 1837, De la Beche was officially told that the accuracy of his survey was in question, and he was encouraged to publish his work as quickly as possible to vindicate his geological interpretation, as well as his skill in the field (Rudwick, 1979). De la Beche did publish in 1839. In his *Report on the Geology of Cornwall, Devon, and West Somerset*, he had partially changed his views and accepted the large synclinal trough in Devon; however, he failed to credit Murchison and Sedgwick for their role in proposing this geological feature. Conversely, De la Beche was correct about the conformity that existed between the Culm (the anthracite contained between the shales and sandstones) of the area and the older strata. The conflict was finally settled with the creation of a new Devonian system, with no participant in the controversy being wholly correct; each geologist changed his views over the course of the fight (Rudwick, 1979).

**Printing as Communication.** Henry De la Beche was correctly advised to publish his work as quickly as possible during the Devonian controversy. Publication of observations and results was the official means of communication. In order for a person to effectively communicate among members of the Geological Society, he must publish. The society did quite efficiently bar women from publishing. As might be expected,

professional surveyors and consultants approached publication in a different manner from the elite gentlemen of the society. Knell (2000) noted that the surveyor William Smith was stifled by the rules of publication; he found effective publication of his use of fossils to be too expensive an undertaking. Porter (1977) concurred, noting that professional surveyors' and consultants' complaints about scarcity of funds forced them to publish in "the cheapest form possible, with little regard for the most effective presentation, and which, especially in the case of William Smith, were a stumbling block to ambitious undertakings" (p. 137). In contrast, the beautifully illustrated *Transactions of the Geological Society of London* contained hand-colored maps, sections, and illustrations. However, Rudwick (1988) noted that the volumes had often been so long in the printing process that their late publication made their contents dated and not as useful. The *Proceedings of the Geological Society of London*, in order to avoid a negative effect on the sale of the *Transactions*, incorporated only brief abstracts of papers. However, Leonard Horner later remarked that the abstracts, being without illustrations, conveyed imperfect ideas of the memoir's nature and value (Woodward, 1907). He also noted that

the great delay in the publication of memoirs in full, robbing authors, in some instances, of the honour of priority in discovery, the uncertainty when a paper that had been read would be published, and even the doubt that was sometimes raised whether it would ever appear, very materially diminished the usefulness of the Society. (Woodward, 1907, p. 81)

Therefore, the benefits of rapid publication were realized, especially in a rapidly evolving subject like geology. The benefits of illustrations were also realized, and were possible in the latter half of the age of focus, particularly with the inclusion of numerous wood engravings or "wood-cuts" within the text.

Although we recognize that illustrations are an important part of geology publications today, illustrations played an even more central role in the science during the

Golden Age of Geology. People in the 1800s were actually trained to study, examine, and contemplate graphics (Rudwick, personal communication, July 3, 2002). Rudwick believed this resulted from the reliance upon the static image, in contrast to today where people are bombarded with the rapid visual sequences of television and movies. During the age of focus, as illustrations became more accessible to the general public, there were print shops which specialized in prints of all types. People collected these, and either had them framed for their walls, or kept them in portfolios. Portfolios became a “library of static images” (Rudwick, personal communication, July 3, 2002), where an image would occasionally be retrieved, placed on the table, and studied. Geological images were undoubtedly used in this fashion.

## Discussion

Although we can divide up history into neat categories for analysis, we never can achieve a total view of the past. Nothing occurs in isolation, and although factors may influence a certain event, it is difficult to identify all the factors that shape the event. However, identifying categories does allow us to ascertain influences during an historical period, and it was in this vein that social and religious factors, technological advances, and the nature of the emerging science of geology were recognized and researched to determine their influence from the years 1788 through 1840.

The Victorian mindset turned people’s attention toward nature during the age of focus; it appears that this influence was partially responsible for bolstering the interest in the evolving science of geology. Although geology was considered a worthwhile interest and endeavor, there were not many employment opportunities in the science at the beginning of the Golden Age of Geology. In this respect, England was far behind continental Europe. Therefore, in the early years of geology, people could be collectors

of earthly treasures, miners or surveyors, or – if they were fortunate enough to belong to the proper social class – elite analyzers and theorizers of the science.

Social status was important. Although there were some exceptions, the status of an individual determined the role that the individual might play in the emerging geological science, in spite of any outstanding contributions he or she might make, or any valuable skill he or she might have. Women, however, were effectively excluded from the elite societies, even if they possessed a proper social pedigree. Therefore, the mindset in the Golden Age of Geology appears to have been that the elite gentlemen theorizers made the lasting and valued contributions in the science. Local information could be gathered from the amateur observers of any class, specimens could be obtained from peasants, but the elite social class must, out of perceived social necessity, propose the theoretical explanations. Higher social status translated into greater knowledge, or at the very least, greater reasoning abilities. Lower social classes could perform physical tasks, but mental tasks must be left to those who were best equipped to handle the difficult theorizing – and these people were the men of the elite geological societies.

History has also most acknowledged the contributions made by those of higher social stature. In particular, most general histories of geology acknowledge the gentlemen theorizers, and not those individuals who observed and collected facts and specimens, or the individuals who produced objects of utilitarian use. It is ironic that most of the individuals who proposed theories that were eventually accepted were often incorrect about their other theories; these have been conveniently forgotten. Whom geology history has remembered, and whom it has forgotten, is obviously not determined solely by the theories proposed. Still, a person of social stature who was accepted into



the societies of science had a much greater chance of making a lasting contribution to geology, as perceived by history.

By the end of the Golden Age of Geology, a new professional middle class had emerged in the sciences. More and more employment opportunities in geology became available as England began to catch up with the rest of the European continent. Rudwick (personal communication, July 3, 2002) agreed that Henry T. De la Beche had been a catalyst for the change that was occurring in Great Britain during his lifetime. As a gentleman of social stature, he was admitted into the Geological Society of London, as well as the Royal Society. When his fortunes failed, he was able to find employment in the field as the director general of the British Geological Survey. This was quite unusual in that he was actually *doing* geology, as well as being able to *theorize*.

Religion appears to have been a double-edged sword that influenced the early geologists' progress. Although religion sanctioned the interest in natural science as reverent, and giving glory to God and His creation, religion partially controlled what could and could not be printed without fear of repercussion. The recent reminder of the storming of the Bastille was an effective deterrent for the scientists who wanted to move too far beyond accepted science; anything approaching criticism of Christianity was unacceptable. However, a general disdain for what was perceived as religious superstition was not considered a transgression.

An ancient age of the earth was generally accepted by the scientists of the day, and literal interpretations of Genesis by scriptural geologists were kept on the margins of the science. The Bible was not discarded altogether, however, but was treated as an ancient text of human history. Geologists, on the other hand, were trying to determine the history of the earth. In trying to reconcile human history with earth history,

interpretations of rocks were often made with the Bible in mind. Incorporating religious references into texts might also be seen as a safety measure.

The new emerging science determined that publication was the key to the transmission of material; this, of course, affected different social groups in different ways. The professional surveyors and consultants could not effectively publish their discoveries and contributions because they did not have the funds to do so. Since they could not afford the books written by the elite geologists of the day, their theories were often dated. Furthermore, they were geographically separated from the theorizing gentlemen in the cities because their work was regional. The elite geologists were under no such restraints. In fact, competition and controversy among the elite geologists encouraged quick publication of opinions and analyses.

Since publication was important, changes in printing techniques during the Golden Age of Geology had quite an impact on the growth of the young science. In particular, illustrations at the beginning of the age of focus were used sparingly: They were expensive to incorporate, and the processes of illustration reproduction mandated printing the illustrations on separate sheets, usually on a different type of paper, before the illustrated pages were incorporated at the beginning or end of the text. With the general use of the wood engraving process by the 1830s, illustrations were much more easily incorporated in texts. They could be printed on the same type of paper, and included in the text. They were also less expensive, which encouraged their liberal application. Since the revolutions in printing in the latter half of the age of focus made texts less expensive, the market in printed scientific texts shifted to the growing professional class. Illustrations were also a selling point in these texts, and this further

encouraged the profuse utilization of illustrations within books and the newly emerging popular periodicals.

In summation, the historical context in which modern geology evolved was complex. Victorian culture, social stratification, religion, and printing advances all had some effect on the emerging science. If we have to identify the factors that most influenced the growing *visual* aspect of the science, however, I believe the development of printing techniques that allowed efficient, economical reproductions was most dominant. A second factor encouraging the visual aspect of geology was the emergence of a middle class of professionals, who clamored for information in affordable books and periodicals. From the latter part of the Golden Age of Geology, the visual nature of the science was firmly locked into place, and has essentially never regressed.

## Chapter 5: Results and Discussion

### The Graphic Innovations and Contributions of Henry T. De la Beche

The role of Henry T. De la Beche and his geology graphics in the emerging field of modern geology, as well as the implications for geology education today, is the research question guiding this investigation. However, before this main research question is discussed, the results of the three subquestions contributing to the main research question will be presented. Chapter 4 discussed the historical context into which modern geology and its visual nature evolved. This chapter concerns the graphic innovations contributed by Henry T. De la Beche to geology and geoscience education, and Chapter 6 will present the nature and progression of early geological graphics in the Golden Age of Geology. These chapters' results and discussions will be combined in Chapter 7 for a final analysis and discussion of the main research question.

#### Henry T. De la Beche

Just as the historical context of the Golden Age of Geology must be considered when judging the progression of geology graphics from 1788 through 1840, so must the background of Henry T. De la Beche (Figure 30) be investigated in order to establish a context in which his illustrations and contributions emerged. His peers recognized De la Beche as an important contributor in the early modern science of geology, but the life he led was certainly not that of the “ordinary” geological contributor in the age of focus. De la Beche participated across various social strata in early modern geology. Although he has never been the focus of a standard biography, some facts of his life have surfaced through his personal and official letters, field notebooks, and publications.



Figure 30: Henry T. De la Beche  
(From Woodward, 1907)

Henry T. De la Beche was born in 1796 in London, England. Although his last name appears to indicate a French background, this is not the case: His father was born Thomas Beach, but changed his name in 1790 to De la Beche by Royal Sign Manual, substantiated only by family tradition that cannot be verified (Chubb, 1958). Sharpe (1997) further noted that the beech wreath included on personal medals, the original family name of “Beach,” and phonetically spelled names in correspondence all indicated that the pronunciation was “beach” instead of “besh.”

Some biographical information on De la Beche was compiled by the geologist himself, written on the flyleaf of an early diary now held in the British Geological Survey (De la Beche, 1816). De la Beche noted that he accompanied his parents to Jamaica in 1800, presumably to visit the plantation owned by his father. With his father’s death in 1801, De la Beche and his mother embarked on a journey back to England; however, they were shipwrecked en route on the island of Great Inagara. Upon his return to England, but before he settled in Lyme Regis in 1812, De la Beche moved frequently. His

handwritten biographical sheet mentioned attendance at four schools from 1802 through 1811, including his entrance into the Royal Military College at Great Marlow in 1809. It was at the military academy that his drawing skills were presumably developed.

Although many historians of geology would later report that De la Beche was not interested in a military career and voluntarily resigned from the military academy, he was, in fact, dismissed for insubordination.

De la Beche's introduction to geology is only speculative. However, he was in contact with the Anning family in Lyme Regis, and was probably introduced to the fossils of the region by them. Unlike Mary Anning, Henry De la Beche was of high social standing, and had more opportunities to advance in the sciences. Although his formal education ended with his expulsion from the military academy, De la Beche continued his geological education through his travels. Like many young gentleman scientists of the time, he traveled to different countries and areas – including Scotland, Wales, and northern England – as part of his unofficial educational experience. De la Beche thoroughly documented his early travels with descriptions and illustrations of his observations in his diaries, some of which are contained in the archives of the National Museum of Wales and the archives of the British Geological Survey.

De la Beche's social status also allowed him access to the great geologists of the day; in particular he developed lasting friendships with William Conybeare and William Buckland. He became a member of the Geological Society of London in 1817, which was then only a young, ten-year-old establishment. Two years later, De la Beche was elected a Fellow of the Royal Society.

Henry T. De la Beche married in 1818, and took his young bride and mother-in-law on a tour of the European continent. His first daughter, Elizabeth, was born in 1819

in Geneva. Geology continued to pique his interest, and his travels included many geological investigations, as well as social fraternizing with the prominent geologists of Europe, including Cuvier, Brongniart, and Breislak. Correspondence contained in the archives at the National Museum of Wales shows that De la Beche maintained these ties with eminent geologists outside England throughout his life.

De la Beche's journal publications begin in 1819; most of the early publications are concerned with original observations made during his travels. Also included in his early papers are several contributions to the original research on ichthyosaurs and plesiosaurs. In 1823, De la Beche returned to the sugar plantation on Jamaica. His scientific mind was well established by this time, and he recorded surface water temperatures and other meteorological observations during his voyage. While in Jamaica, he improved the living conditions of the slaves on the plantation, and acquired the disapproval of other planters in the process. Geology continued to be a prime interest during this trip: De la Beche investigated the geology of the island, and described his findings in his correspondence with Conybeare. He published the first known geological map of the island, and eventually became known as the "Father of Jamaican Geology" (Sharpe, 1998-1999). Years later, Charles Darwin would seek his observations on the fauna of Jamaica, with special reference to any unusual mutations detected there (McCartney, 1975).

De la Beche's first book appeared in 1824, a translation of various geological papers from continental Europe. Unfortunately, his private life did not enjoy the same success as his geological one; he and his wife separated in 1825, eventually to divorce. De la Beche never remarried. De la Beche's geological career continued, and books of his original work appeared in 1830, with the publications of *Geological Notes* and

*Sections and Views, Illustrative of Geological Phænomena*. In 1831, *A Geological Manual* was first published, and proved to be one of De la Beche's most successful works, eventually issued in several editions as well as several translations. Unlike Charles Lyell, who would attempt a unifying theory of the earth, De la Beche shied away from any grand theorizing in his books. This is true even with the 1834 publication of *Researches in Theoretical Geology*. De la Beche publicly stated that geology was far too young a science to unify with grand theories; there was only a limited amount of evidence available (Sharpe, personal communication, July 11, 2002).

De la Beche began mapping the rocks in Devon in the 1830s, but financial hardships due to the failing Jamaican plantation caused him to turn to the government for the funding to continue. His memorandum promised the geological structure of the district, with accurately scaled detail, and a final product ready for transfer to Ordnance copper plates (North, 1944). De la Beche's appeal was successful, and he was awarded £300 to complete the topographic descriptions and coloring of his maps. Another daughter – illegitimate – was born during his fieldwork in Devon. When this first mapping task was completed, De la Beche again appealed to the government for funding in order to continue mapping in Cornwall. Thus, in 1835, the Ordnance Geological Survey – the forerunner to the British Geological Survey – was established, with De la Beche at its head. Flett (1937) noted that De la Beche was well suited to the task: He was diligent, methodological, and well versed in collecting and interpreting evidence from the field. De la Beche appears to be the first full-time English professional geologist who was unassociated with a university, employed at a salary of £500 per year by the British government. While De la Beche's geological skills earned him the position, Eyles and Eyles (1955) reported that De la Beche then proved himself an able



administrator, possessing the qualities of “tact, firmness and an understanding of the official mind so necessary to one in his position” (p. 659). Reyment (1996) also noted that De la Beche was truly representative of the beginning of the transition from “the heroic and the clever artisan to the functionary of the State” (p. 489). Not everyone appreciated the transition, however. Gideon Mantell, a contemporary of De la Beche’s, made rather biting remarks about De la Beche’s new position. In particular, Mantell noted that although De la Beche was once a “very rich West Indian proprietor, and travelled a good deal,” he was “much reduced in circumstances, and is employed by the Government to colour geologically the Ordnance maps” (McCartney, 1975, p. 28). Mantell accused De la Beche of plagiarism, and stated he could not hold him in high esteem. McCartney felt that the negative comments reflected the views of the gentlemen geologists of the time; since De la Beche was forced into a position as a working geologist, he was no longer a full member of that elite group.

Further troubles erupted with the Devonian controversy. This controversy embroiled De la Beche’s early professional life, and began when either Adam Sedgwick or Roderick Murchison obtained De la Beche’s completed, but unpublished, map of Devon without De la Beche’s knowledge or consent (McCartney, 1975). De la Beche declared that fossil plants usually associated with coal-bearing strata were found in the older, “transition” rocks. Murchison and Sedgwick toured the area in question, map in hand, and then declared the map inaccurate at the Bristol Association for the Advancement of Science in 1836. De la Beche, angry at what was perceived to be an underhanded attack, felt his professional competence was questioned. Although he thought about tending his resignation in 1837, he ultimately survived the attack, but did

have to alter his original interpretation of the geology of the area. However, everyone involved in the dispute eventually emerged with changed views.

In 1845, the British Geological Survey was reorganized, and was formerly transferred from the control of the Master-General and Board of Ordnance to the First Commissioner of Her Majesty's Woods, Forests, Land Revenues, Works and Buildings (Chubb, 1958). De la Beche generally remained in London from this point forward. He served as president of the Geological Society of London from 1847 through 1849. Another of his endeavors, begun shortly after his official hiring as Director General of the Survey, also came to fruition: De la Beche had asked for permission to have geological specimens collected for future public exhibit. Rudwick (1985) noted that since De la Beche was the first professional geologist of Britain, he was on precarious ground; therefore, he essentially spread his risks between two government departments. While the mapping project was originally under the Board of Ordnance, the collection of museum specimens was under the Department of Woods and Forests. The Museum of Practical Geology was the eventual result of the museum collection; Prince Albert formally opened its doors in 1851. The School of Mines and the Mining Record Office were also established, largely through the efforts of De la Beche. In his official position, De la Beche made contributions of economic and industrial importance, including inquiries into building stones and steam coal. His professional efforts were obviously appreciated by the official governmental powers; in 1842, De la Beche was rewarded with knighthood.

In 1851, Henry T. De la Beche began to show signs of a disease that would eventually consume him. Partial paralysis initially caused lameness, but eventually confined him to a wheeled chair. Although his health continued to deteriorate, De la

Beche remained at the head of the British Geological Survey, still very much involved with the operations. In 1855, he was awarded the Geological Society of London's highest honor, the Wollaston Medal, but was too sickly to attend and accept it on his own. Ironically, Roderick Murchison, with whom he had fought the public Devonian controversy, accepted the medal on his behalf. De la Beche visited the Museum for the last time on April 11, 1855; two days later, on Friday, April 13, 1855, he was dead.

Henry T. De la Beche was well known during his lifetime, first as a member of the elite group of gentlemen geologists, and then as the first professional government geologist of Britain. McCartney (1977) noted that his contemporaries recognized him beyond his written and professional accomplishments. Not only was De la Beche acknowledged as the founder of the eventual British Geological Survey and the Museum of Practical Geology, but also his talents as a draughtsman and artist were recognized from his preparation of geological maps and sections, his self-drawn illustrations for publications, and his comic portrayal of scientific controversies in the form of scientific caricatures. De la Beche's graphic contributions to the young science of geology will now be considered.

### Identification of Graphic Categories

The presentation of the graphic innovations and contributions of Henry T. De la Beche to geology and geoscience education is facilitated through a categorization of his various illustrations. It became apparent to me as research proceeded that this classification can be accomplished in two obvious ways: Categorization can proceed through the different types of illustrations, or categorization can occur through the different types of publications. Fortunately, there is a fairly close match between the type of illustration and the type of publication. Since the publication categories are slightly

more distinct, I chose to utilize the different publication vehicles of illustrations in order to classify and analyze De la Beche's graphics. Therefore, this discussion shall proceed through De la Beche's illustrations included in periodicals, books, official government publications, and field notebooks, as well as miscellaneous illustrations. It should be noted that although some papers were republished in several journals, only the original articles were considered in this research investigation. One exception to my categorization schema was made: The caricatures, which are found in field notebooks and letters, as well as separate prints, were considered a separate group. Caricatures are so distinctive a graphic type that they warrant a separate category and discussion.

### **Illustrations in Periodicals**

Although Henry T. De la Beche was accepted into the prestigious Geological Society of London in 1817, his official life as a geological contributor did not begin until he effectively communicated in the accepted medium of the times, and published in a respected journal. Appendix K charts the majority of De la Beche's journal publications, and summarizes the ones that were investigated in this research study. De la Beche's very first paper of 1819 described depth and temperature observations of the Lake of Geneva in *Bibliothèque Universelle*. De la Beche's visual expression had not yet found its outlet, and there were no included graphics in the text. His second paper, on the same topic, was published in 1820 in the *Edinburgh Philosophical Journal*; this paper included one map referenced as a plate. A photograph of this map is presented in Figure 31. Although his early papers did present data in tabular form, De la Beche, like most geologists in the age of focus, did not take the next step and represent data as mathematical graphics.

De la Beche, with William Conybeare, contributed original research on ichthyosaurs and plesiosaurs in the 1820s. The first of these publications dealing with

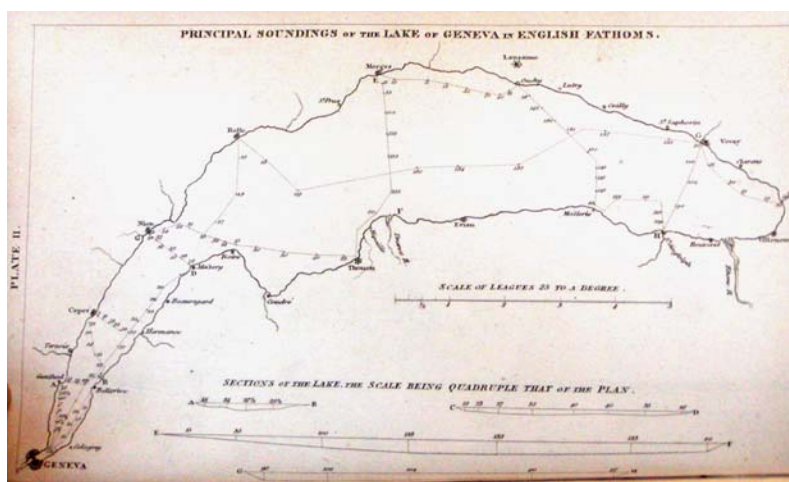


Figure 31: Map of the Lake of Geneva, from De la Beche's first published paper with a graphic. Direct labels are included, as well as a scale and a profile. (From De la Beche, 1820b)

fossilized remains was the 1821 paper in the *Transactions of the Geological Society of London*. Graphic depictions were an integral part of this paper, and De la Beche's illustrations were executed in the fashion of Georges Cuvier, with precision and direct labels. Plate 40 from this article is presented in Figure 32. Although Hineine (1993) categorized geology illustrations as either proxies or diagrams, some of the figures in the included plates cannot be described as simple proxies, but do not approach the category that Hineine defined as diagrams. De la Beche *inferred* information from the fossilized remains, and dashed lines indicate knowledge that is not directly observable from the actual fossil. However, De la Beche's inferences did not allow the viewer to make *generalizations*; Hineine stipulated that diagrams, in contrast to proxies, allowed generalizations about nature. It should also be noted that the illustrations of the papers were incorporated as *plates*, and were not included as figures directly in the text. Wood engravings had not yet found widespread use.

Although wood engravings were not yet popular, De la Beche utilized a fair number of illustrations. In fact, his 1822 paper on the geology of the south coast of

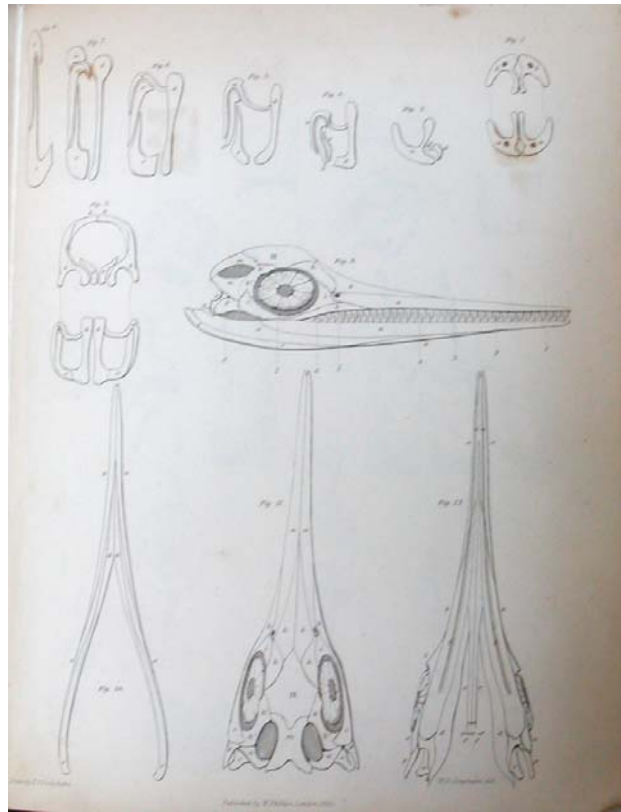


Figure 32: Plate 40, in a style similar to Cuvier's, which employs direct labeling of a proxy image. (From Conybeare & De la Beche, 1821)

England is remarkably well illustrated for a rather small eight-page paper. De la Beche (1822a) included illustrations of fossils as well as sections, some hand-colored. Plate VII, showing hand-colored fish and plant fossils, is shown in Figure 33. De la Beche maintained the direct labeling of graphics, and still inferred information from actual specimens; Figure 1 of Plate III has a dashed line showing the *probable* outline of a fossil within the matrix. Some graphical unsophistication is evident, however: De la Beche does not refer to his plates in the order they are presented in the volume. Likewise, another 1822 paper (De la Beche 1822b) contains three plates in the publication. Only one is referenced in the text, although the other two are bound with the referenced plate. However, De la Beche did include hand coloring on some of these graphics, and posted a color key. Direct labels and a scale were also utilized.

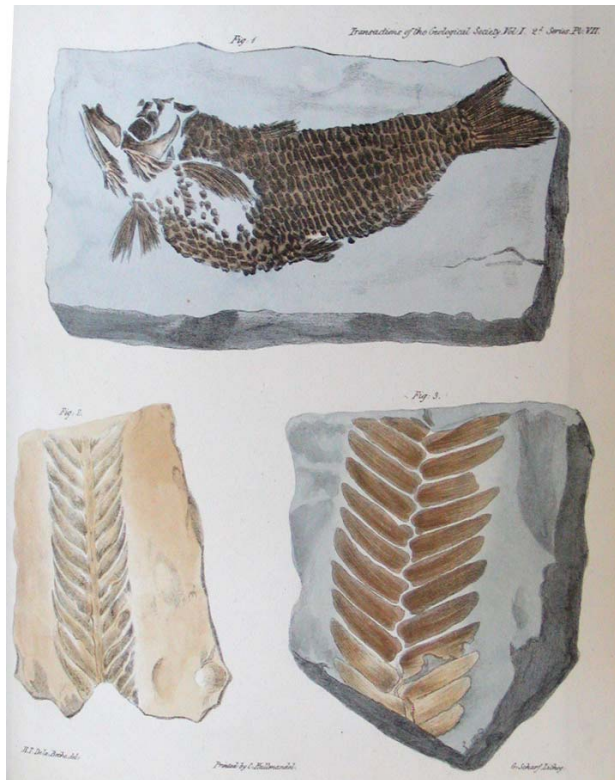


Figure 33: Hand-colored illustrations of fossils.  
(From De la Beche, 1822a)

Not all of the early De la Beche publications are illustrated. Many of these early papers were in the form of very brief, two-page papers; these do not include any illustrations. Another longer publication in the *Zoological Journal* in 1825 contains no illustrations either (De la Beche, 1825a). Since De la Beche was submitting papers for publication, the absence of illustrations in an article cannot be taken as evidence that he did not want to include graphics. Editorial and publisher decisions may have taken precedence over his wishes. Furthermore, some journals, such as the *Proceedings of the Geological Society of London*, tried to circulate research findings in a timely fashion; the addition of illustrations would be time consuming to the publication process.

An 1825 publication in *Annals of Philosophy* marked the use of a new illustrative technique for Henry T. De la Beche: The short paper was illustrated with two wood engravings, which were incorporated directly in the text. This technique was an obvious

improvement for the reader's efficiency; a person would not have to flip back and forth between text and illustrated plates at the back of a volume. Although the graphics are simple, they do incorporate direct labels and alphabet labels. The first illustration on page 54 of the text is shown in Figure 34.

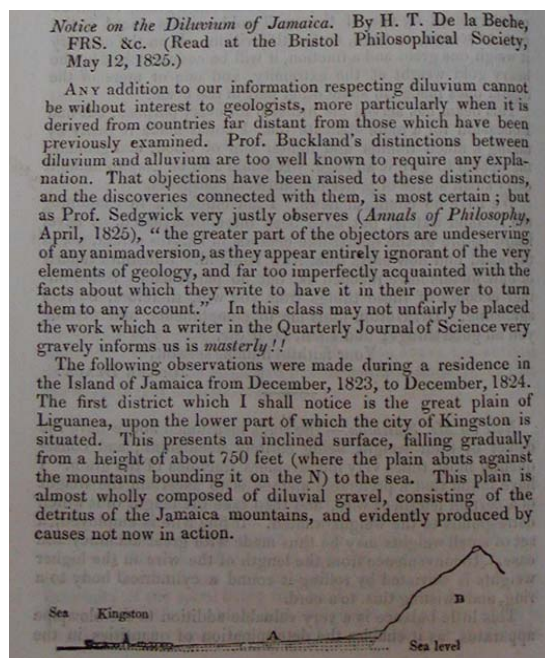


Figure 34: The first published De la Beche wood engraving, with direct labels and alphabet labels. (From De la Beche, 1825b)

Just as De la Beche most likely did not have complete control over the inclusion of graphics to illustrate his papers, he almost certainly was not the only person deciding whether his illustrations would be presented as wood engravings incorporated within the text or plates inserted at the back of the publication. In the 1820s, wood engravings were just becoming a common method for illustration reproduction, and undoubtedly the publisher of the periodicals influenced their use. In 1826, De la Beche published another paper in the *Transactions of the Geological Society of London*, and the included illustrations reverted once again to being incorporated as plates at the end of the volume. Interestingly, in this paper, a color key was originally included; however, a plain piece of





wood engravings were omitted in De la Beche's 1826c paper, the 1827b paper, and the 1829b and 1829c papers of the same journal. Plates were used for all graphic vehicles; one reason may have been that the sections, maps, and fossils demanded finer detail than the wood engravings could provide. Plate 18, depicting the geological map of Devon and sections in the 1829b paper, is shown in Figure 36.

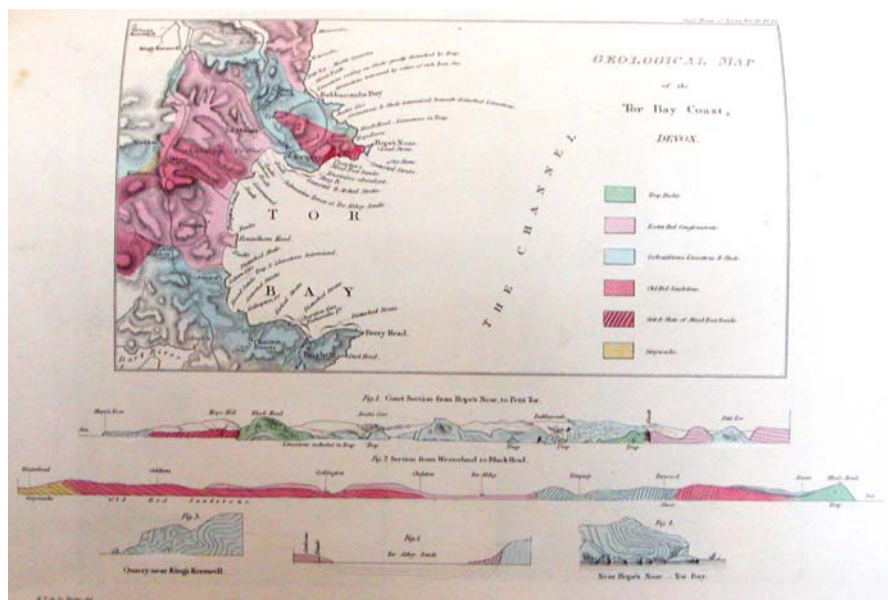


Figure 36: Geological map and sections of Devon, with direct labels, hand coloring, and key. (From De la Beche, 1829b)

An 1835 paper, co-authored with William Buckland, was prolifically illustrated. The 46 pages of text contain four wood engravings, including sections with direct labels, one with a scale in feet, and one with wrap-around text. In addition to the wood engravings, three plates are cited often (on 16 occasions) with the text. No expense was spared with the reproduction of the plates: Plate I is a hand-colored map that is reinforced with cloth. It includes a color key and a scale. The other two plates contain sections; while a color key is printed with Plate II, there is no reproduction of the key for Plate III. Presumably it is the same as that on Plate II.

While the age of focus for this research was the Golden Age of Geology, 1788 through 1840, papers of De la Beche that were published after the age of focus were also investigated in order to ascertain any possible trends in De la Beche's types and uses of illustrations. However, there are very few De la Beche periodical publications after 1840; most of his publications were in the form of texts or reports of official government business. The few De la Beche papers published after 1840 were not illustrated, or only marginally illustrated. For example, an 1844 paper that appeared in *Philosophical Magazine* included two wood engravings of a map and a very simplified profile.

### **Illustrations in Texts**

Henry T. De la Beche entered into the official discourse of the emerging science of geology with the publication of his first paper in 1819. Ten years later, he had already published 27 articles in several different journals; this decade, 1819-1829, was his most prolific for periodical publications of original observations and research. The next two decades would witness a decrease in the publication of articles. However, De la Beche did not abandon the printed page altogether: Instead he focused on different genres.

De la Beche's first text was released in 1824, the first of nine published texts throughout his geological career. A list of his texts, along with notations of different editions and translations, is included in Appendix K. It is interesting that the first published text by De la Beche was not his original work. Instead, in 1824, De la Beche translated several papers from the *Annales des Mines* for his English contemporaries. De la Beche was noted for having good contacts with the rest of European geologists beyond the English Channel; he was also aware that the continental countries were far ahead of England in government participation in geology (Rudwick, personal communication, July 3, 2002). De la Beche (1824a) stated his purpose for translating the papers in the preface:

I have endeavoured in the following pages to collect much valuable Geological information, which was scattered through several volumes of the Annales des Mines, a word edited by the General Council of Mines at Paris; and it is hoped that thus presenting it in a portable form, it may be found useful to English Geologists, by enabling them easily to compare some of our own rocks with similar formations described in the above work; a correct knowledge of the changes which take place in many rocks, particularly those of the secondary class, in their mineralogical structure, & c. at different distances, being I conceive not one of the least important branches of geological inquiry. (p. iii)

De la Beche was attentive to the fact that the science of geology was still in its infancy, and he attempted some correlation between the knowledge – in the form of observations – that had been collected on the European continent and the knowledge that had been uncovered through observations in England. However, he was also aware that difficulties might be encountered in linking the foreign geological formations with the English ones. He solved this problem by adding a Synoptical Table of Equivalent Formations, whose arrangement, he stated, was “simply that of convenience, and [I] wish it to be clearly understood that it is no attempt at geological divisions” (De la Beche, 1824a, p. iii). The table, although not in graphic form, is a clear attempt by De la Beche to organize information for his readers, and facilitate the education process.

However, De la Beche did recognize the importance of visual display. He included a total of 11 plates in the text, inserted at the beginning and end of the book. While Plate II was inserted before the text as a frontispiece, the other 10 plates followed the text and tables. Some plates included more than one figure; when the total number of figures is counted, a total of 22 images result, not including numeration of the many fossil figures of Plate VIII. De la Beche included two colored maps with keys. He also employed direct labels and alphabet labels for identification. One of the more unusual illustrations in this volume has already been reproduced in the introduction, and can be seen in Figure 15. Plate IX is also unusual in that it depicts a section, cut away in the

center, into which a landscape view is added. The two figures incorporate direct labels and alphabet identification. Plate IX is shown in Figure 37.

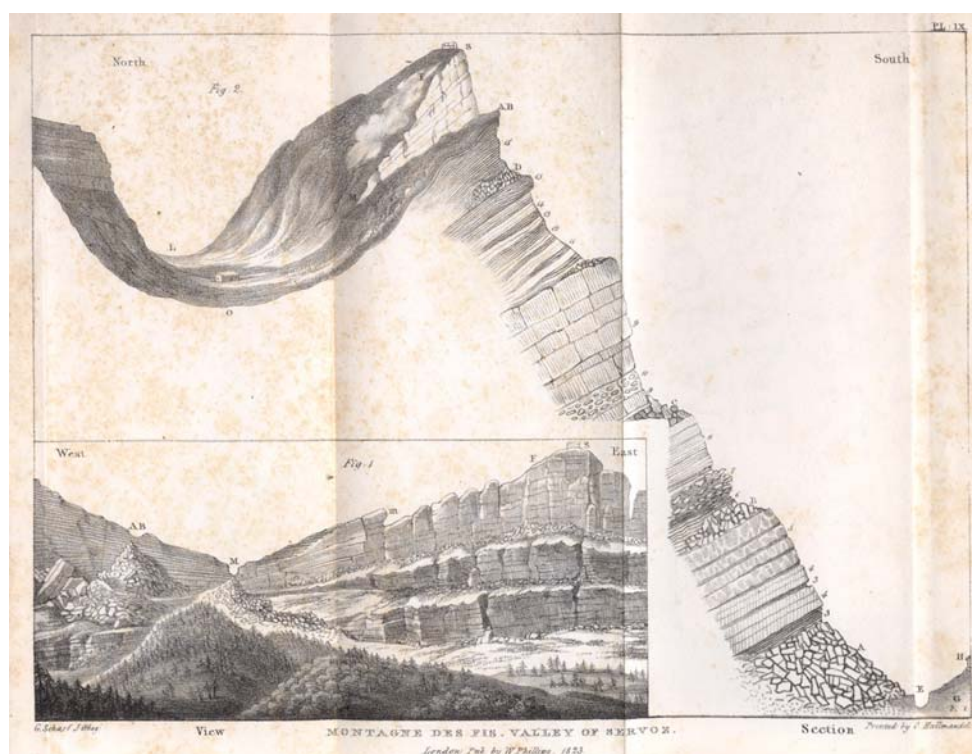


Figure 37: Plate IX from the 1824 translation of papers from the *Annales des Mines* includes direct labels, alphabet labels, and both a sectional and landscape view. (From De la Beche, 1824a)

De la Beche may not have been entirely happy with his first book. In a letter to William Conybeare, he remarked that of the translations, he wished “I had never undertaken, or put in the way of publication” (De la Beche, 1824b). However, the book was eventually republished in its original form in 1836. De la Beche’s next books would mark a change of venue, with the texts consisting of De la Beche’s own observations, and not translations of others’ research.

In 1825, De la Beche published a text of his observations on the treatment of slaves in Jamaica. *Notes on the Present Condition of the Negroes in Jamaica* is a small, 63-page volume that marks the only De la Beche book departing from the geological perspective. Only one illustration is included: The frontispiece is a hand-colored graphic

depicting “Jamaica Negroes Cutting Cane in Their Working Dresses” (De la Beche, 1825c). The illustration is totally pictorial in nature, with no additional information added. It typifies the perfect Hinkel (1993) proxy since it portrays a scene, without any supplementary inferences or interpretation by the graphic’s creator.

De la Beche did not venture into book publication again until 1830. However, in this year, he completed two different works: *Geological Notes*, and *Sections and Views, Illustrative of Geological Phenomena*. Of these two works, *Geological Notes* was the lesser of the texts, and did not have the lasting impact that *Sections and Views* did. *Geological Notes* is a slim, 69-page volume, with only two graphics included at the end of the text. Plate II actually precedes Plate I, and is a reprint from the 1829d article in *Philosophical Magazine*. This plate is reproduced in Figure 16. The other plate incorporated four figures in the form of simplified annotated map views. Although direct labels and a compass arrow are used in the illustrations, the graphics do not convey a lot of information; data density is moderately low.

*Sections and Views, Illustrative of Geological Phenomena* is an exceptional text, however. Both Martin Rudwick (personal communication, July 3, 2002) and Tom Sharpe (personal communication, July 11, 2002) commented on the importance and innovative nature of the text. According to Rudwick (personal communication, July 3, 2002), De la Beche wrote *Sections and Views* in order to provide a series of proxies for himself and his contemporaries; by providing the detailed observations of the field, De la Beche was making available the *source* of the phenomena, which needed to be taken into account when theorizing. Sharpe (personal communication, July 11, 2002) concurred that *Sections and Views* was extraordinary; De la Beche’s reason for writing it was to make facts known to his fellow geologists. This motive is parallel to the stated purpose of the

1824 text, in which De la Beche wanted to make available, through translation, the research of continental geologists.

The text includes 40 plates, which are of varying quality; Sharpe (personal communication, July 11, 2002) commented that the Jamaican illustrations in *Sections and Views* were “rougher.” Of the 40 plates, with 137 figures, only 6 plates, with a total of 14 figures, are purely pictorial; all others have labeling or have been modified with additional information. Maps and sections are multivariate. Coloring is selectively used: The 24 colored plates are mostly sections that employ color as rock and strata discriminators. Conversely, pictorial views are not colored. Direct labeling, alphabet labels, and keys are also used. Figure 17 reproduces Plate 5, a typical illustration from the text.

De la Beche was adamant about not theorizing in the new science of geology. He believed that the field of geology was too young, the earth had not been adequately explored, and not enough facts had been made available to support one theory or another. He explicitly stated

The following sections and views are not intended to support or oppose any particular theory: the sole object in collecting them together has been utility. Theories, no doubt, are useful to a certain extent, for they promote inquiry; and in the present day, a few facts, at least, must be brought forward to support them. . . Thus, new countries are explored, and old districts re-examined; facts come to light that do not suit either party; new theories spring up; and, in the end, a greater insight into the real structure of the earth’s surface is obtained . . . It would be much more desirable that facts should be placed in the foreground and theories in the distance, than that theories should be brought forward at the expense of facts. So that, in after times, when the speculations of the present day shall have passed away, from a greater accumulation of information, the facts may be readily seized and converted to account. (De la Beche, 1830b, p. iii - iv)

De la Beche also specifically promoted an *accurate, unexaggerated* portrayal of the facts in his illustrations. Since facts should be made available to geologists, and since

the knowledge gained from one hundred facts is more valuable than that knowledge gained from only a handful of facts, De la Beche advocated a perfect representation of facts in graphic form so that future geologists would be able to retrieve correct, unadulterated information. Plate 2 in *Sections and Views* presents different geological sections, and portrays the perils involved in depicting scenes with exaggeration. It is interesting that this plate was obviously considered valuable to later geologists: It was partially reproduced in Mather and Mason's (1939) *Source Book in Geology*. Their reproduction is depicted in Figure 38. This figure continues to be utilized today: Dr. Brian Lock, Professor of Geology at the University of Louisiana at Lafayette, has informed me that he uses this graphic in stratigraphy classes (Lock, personal communication, January, 2002).

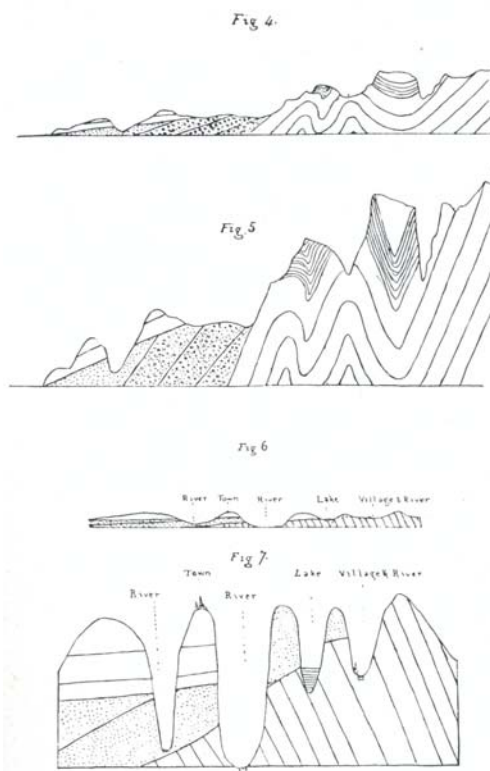


FIG. 13.—Four of the figures used by De la Beche to illustrate his ideas concerning the drafting of geological sections, 1830.

Figure 38: Reproduction of De la Beche's (1830e) Plate 2 figures. (From Mather & Mason, 1939)



Some of the De la Beche graphics in *Sections and Views* are drawn in pseudo small multiple format. This is especially true of geological sections, which are presented as a series of several levels of graphics within one plate. Figure 39 reproduces Plate 3 from *Sections and Views*; Plate 3 can be classified as a small multiple graphic, hand-colored, with direct labels and a color key.

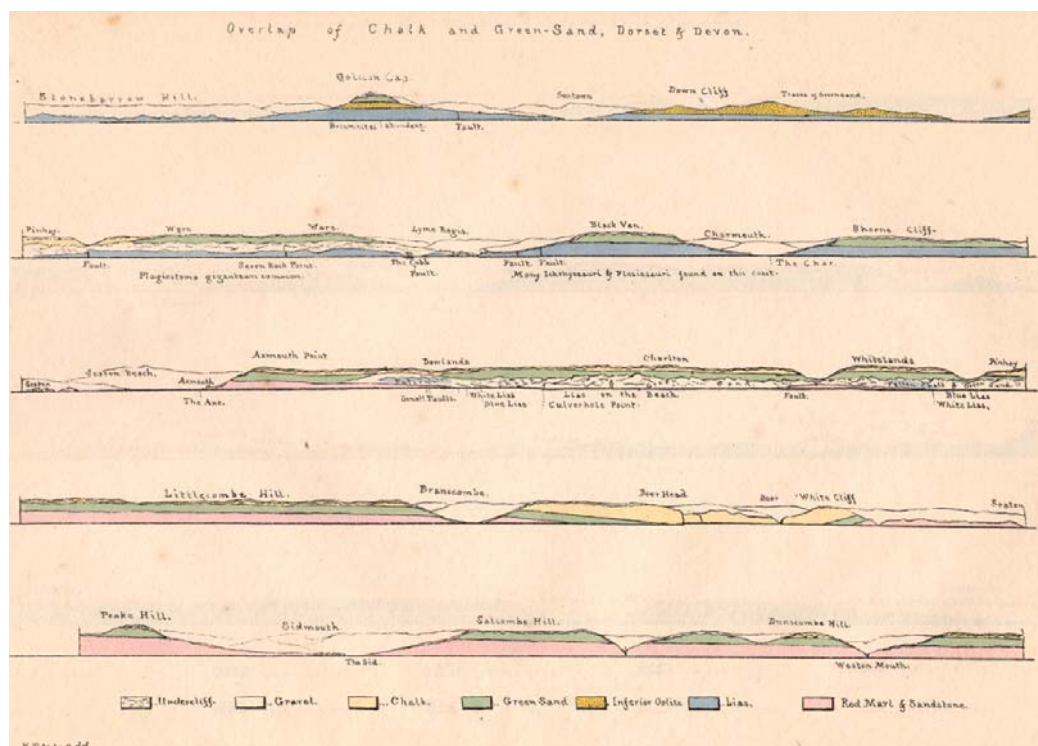


Figure 39: Plate 3 from *Sections and Views*. Note the small multiple format, in which the sections change as a variable across the landscape. A color key is included at the bottom. (From De la Beche, 1830e)

The lithographs in *Sections and Views* allowed for reproduction of detailed images; although the method was expensive, the quality of the images was superior, and the hand-colored graphics were artistic and visually pleasing. However, De la Beche's fourth book, *A Geological Manual*, moved away from the more elite lithographic reproduction and utilized wood engravings. Wood engravings did have several advantages: They allowed for images to be incorporated *within* the text, instead of inserted as a plate in front of, or behind, the text. Wood engravings were also relatively

inexpensive as a means of illustration reproduction, especially when their use had become commonplace. Therefore, wood engravings allowed more illustrations in a text, facilitated the reader's viewing of graphics, and made illustrations more accessible to the reader of lower social status.

*A Geological Manual*, first published in 1831, was De la Beche's most reproduced text. In addition to the three English editions, the work was also translated into French and German. Woodward (1911) stated the text was highly regarded by contemporary geologists, while McCartney (1977) believed the value of the text continued, as it "remains to this day an extremely valuable source for the historian of geology, since its 'manualistic' thoroughness documents the researches of Europe's most active geologists" (p. 28). However, Gillispie (1959) thought that De la Beche's avoidance of theoretical discussion as well as Biblical overtones resulted in a text that was moderate in view and therefore rather "dry."

Regardless of the textual overtones, *A Geological Manual* marked a new frontier for De la Beche illustrations. Wood engravings made the inclusion of many illustrations within a text feasible. De la Beche included 104 wood engravings in both his 1831 original publication and his 1832 English second reissue. Some slight modifications were made in the expanded English third edition in 1833 (122 wood engravings), the first French translation in 1833 (107 wood engravings), and the second French translation in 1836 (105 wood engravings). A more pronounced difference occurred in the German translation of 1832; this text was much reduced in illustrations for a total of only 24 wood engravings. However, the length of the German text did remain similar to the English and French versions.

The different formats of illustration in *A Geological Manual* included geological sections, maps, pictorial representations, and fossil drawings. Alphabet labels were maintained in the text, but missing were the direct labels that De la Beche had utilized in his 1830 lithographs. Whereas most of the illustrations were similar between texts, there were slight differences. Placement of illustrations – whether side-by-side, within text, or centered between blocks of text – often differed between the English editions and translations. The English editions had finer line widths, resulting in cleaner images with less chartjunk. Figure 40 presents an English and a French version of the same

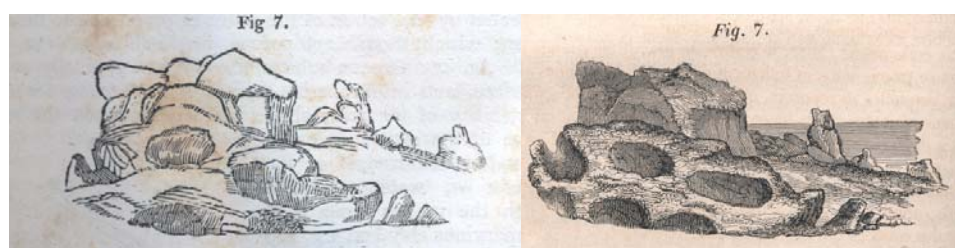


Figure 40: Differences in line width and detail in the left 1832 English edition of *A Geological Manual* and the right 1833 French version of the same. (From De la Beche, 1832b, 1833b)

graphic. Differences also existed between versions with the inclusion of human figures (Figure 37 in De la Beche 1832b, 1833b) and “fluff” in images, such as the addition of a boat in a river, as shown in Figure 41. Some fossil figures (figures 86-92 in 1831, compared to figures 89-95 in 1833b) appear to have been entirely redrawn in the French version (1833b) from the English edition (1831). The possibility exists that these

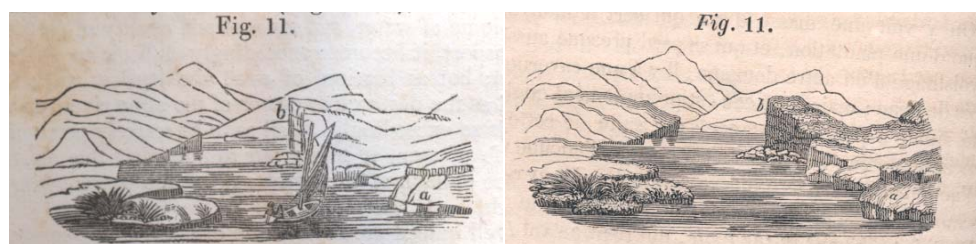


Figure 41: Differences in detail in different versions of *A Geological Manual*. Note the absence of a boat in the French translation on the right. (From De la Beche, 1832b, 1833b)

graphics were embellished by the engraver, or changed per De la Beche's instructions. Other small differences may have resulted from slight variations in reproduction among publishers and machinery.

However, there were a few more marked differences between texts. The German translation included very few graphics, and failed to number them. The included graphics were identical to some of the graphics in the English and French versions, however. An unusual graphic form – reconstructions of ancient life – was included in the 1833 French translation and the expanded English edition. De la Beche created three vignettes of extinct life from fossils and their contextual clues; he acknowledged in his text that he followed the format of Cuvier. Rudwick (personal communication, July 3, 2002) remarked that they represented the first time a scene from deep time was put into a modest form, instead of a large, expensive picture. A graphic that included a plesiosaur and pterydon is reproduced in Figure 19. Another reconstructed scene from geologic time is shown in Figure 42.

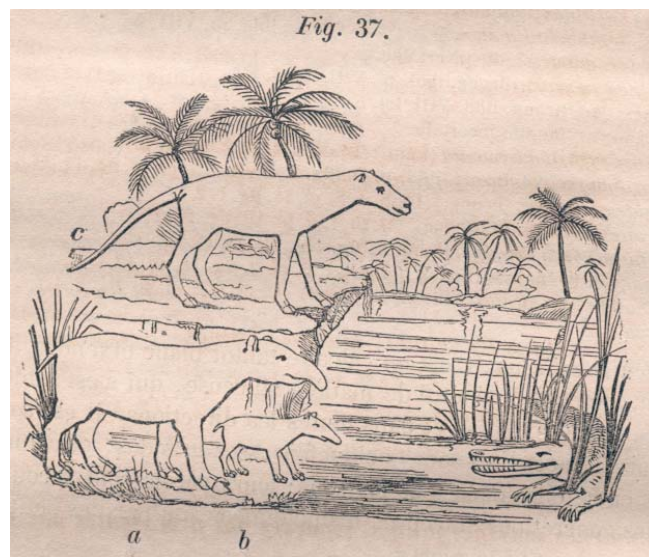


Figure 42: One of De la Beche's three vignettes of ancient life in the French translation of *A Geological Manual*. (From De la Beche, 1833b)

Although the title may lead the reader to presume that De la Beche had abandoned his dislike of universal theories, *Researches in Theoretical Geology* does continue to promote the favoring of facts and observations above theoretical considerations. De la Beche (1834b) explicitly stated,

Although the theory of central heat and the former igneous fluidity of our planet have been much dwelt upon in the following pages, the author trusts that he will not be considered so attached to these views as not to be ready to reject them and embrace others which may afford a better explanation of an equal number of observed facts, should such be brought forward. (p. v).

Although De la Beche did not propose a grand theory that would unite all geological observations, he did attempt to integrate geology with other sciences. The included graphics appear to have a more mathematical orientation than those of his previous texts; Figure 21 reproduced a graphic from the text that showed differences in pressure and temperature from a coastline. However, De la Beche did not make this text as visual as its predecessor, *A Geological Manual* (1831). Only 46 wood engravings were included within the text, with more images being incorporated in the beginning of the text. Different types of illustrations included maps, sections, and pictorial scenes. Depictions of experiments, as well as true and exaggerated portrayals of the earth's relative crustal relief, are incorporated also. Alphabet labels were used, but direct labeling was sparingly used. Figure 43 shows a small multiple graphic of sectional views that did include direct labeling. The different editions of this work incorporate essentially the same graphics; the variations noted in the different editions and translations of *A Geological Manual* are not seen. In general, the wood engravings are very simple. Gone are the heavy lines of the French translations of *A Geological Manual*, as well as in-depth detail in the illustrations.

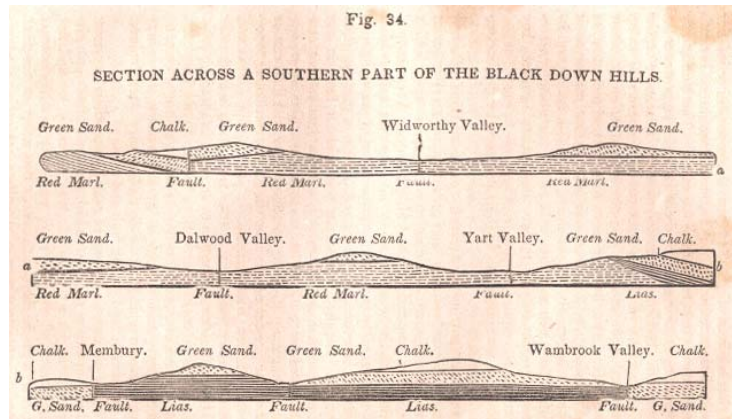


Figure 43: Geological sections in small multiple format, incorporating direct labeling. (From De la Beche, 1837e)

Included as the frontispiece for the original 1834 publication was a view of the earth from outer space. Drawn by De la Beche, it is a rather enlightened pictorial representation of an inference; obviously, De la Beche did not have the ability to actually view earth from this perspective. Unfortunately, this frontispiece was removed in the 1837 reprinting, as well as the French translation. Figure 44 reproduces the frontispiece from the original 1834 text.



Figure 44: The earth as viewed from space. (From De la Beche, 1834b)



De la Beche's next book contribution was the 1837 text, *How to Observe*. *Geology*. If De la Beche had ignored his visual nature by including fewer graphics in *Researches in Theoretical Geology*, then he most certainly reclaimed the illustrative component of his texts in *How to Observe*. One hundred thirty-eight wood engravings are included in all versions of this text; the book was ultimately printed in two English editions, as well as French (1838a) and German (1836) translations. The illustrations are more numerous, but also appear to be more detailed. Many of the graphics appear to be direct variations of illustrations that were included in earlier works. Alphabet labels are still incorporated, and to a much lesser extent, direct labeling as well. Graphic types include sections, pictorial views, and technological representations. Figure 20 reproduces an unusual illustration included in the book: De la Beche included a graphic metaphor for teaching strike and dip. De la Beche also added *directional* information to some of his graphics. Figure 45 reproduces two wood engravings in *How to Observe*, which superimpose directional movement of earthquake waves over a map.

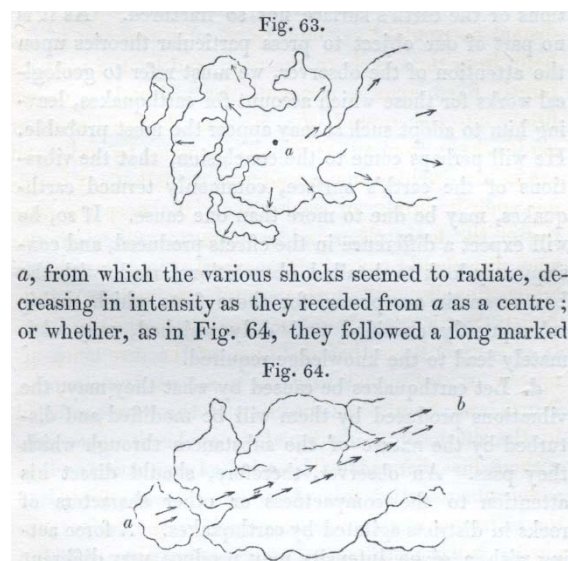


Figure 45: Figures from *How to Observe* that have a directional component overlaid on a map. (From De la Beche, 1835)

Graham McKenna (personal communication, July 16, 2002) believed that De la Beche's *How to Observe Geology* books were particularly innovative. There was an element of education and teaching behind the text; this complemented other De la Beche missions, including the encouragement of the workingman's lectures.

De la Beche's seventh text was the 1839 *Report on the Geology of Cornwall, Devon and West Somerset*, which definitely was a product of stressful times. With his *professional* interpretations being challenged by some of his colleagues, De la Beche was advised to publish his work as quickly as possible in order to vindicate himself. This text was the result.

De la Beche's graphic representation changed in this text to incorporate both plates and wood engravings. A total of 13 plates and 84 wood engravings were included. Alphabet labels were still the dominant addition to graphics, although more wood engravings incorporated direct labeling and keys than previous texts with only wood engravings. Although *interpretations* were made, it does not appear that De la Beche abandoned his dislike of grand theorizing, or promoted the transference of his interpretations to other geological anomalies.

Many of the illustrations appeared to be constructed for the viewer's educational facilitation, and were not simply pictorial – or structural – representations. Figure 46 shows three figures from the text. In order to explain a certain observed phenomenon, De la Beche *simplified* and *illustrated* his observations. The resulting graphic greatly aided the reader's understanding. De la Beche may have felt such educational graphics were a necessity: He was trying to persuade his geological contemporaries of his interpretations in Devon, as well as his competence as a field geologist.



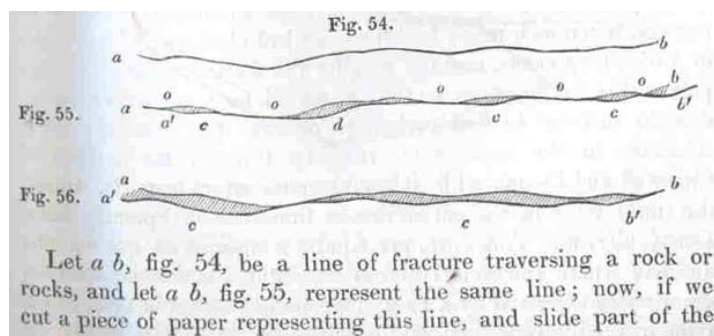


Figure 46: Simplified wood engravings incorporated by De la Beche to facilitate a reader's understanding of his observations. Note the use of alphabet labels. (From De la Beche, 1839b)

The final text produced by De la Beche is the expanded *The Geological Observer*, first published in 1851. In 1853, it was republished as a second English edition and translated into German. Although this text was published outside the age of focus, 1788-1840, it was investigated in order to determine whether De la Beche's graphic style had undergone further evolution. The book was prolifically illustrated: The first edition's 740 pages incorporated 308 wood engravings. Many of these illustrations are exact copies of illustrations in earlier works, or have only been slightly altered. Most diagrammatic representations were very simple in line density and line width; pictorial representations were more heavily inked and shaded, perhaps in an attempt to achieve an accurate, natural portrayal. Figure 47 shows a representative sample of a heavily inked pictorial representation, or proxy.

De la Beche did continue to use directional annotations over basic maps in *The Geological Observer*; Figure 48 reproduces an educational diagram that illustrates a basic movement of sand. If a new graphic addition can be identified in the 1851 text, it is the graphic form that incorporates multiple numbers as data directly within the illustration. Figure 49 replicates one of these graphics; the numbers on the map represent depth, in



Figure 47: Pictorial representation, or proxy. Notice the heavy use of ink. (From De la Beche, 1851a)

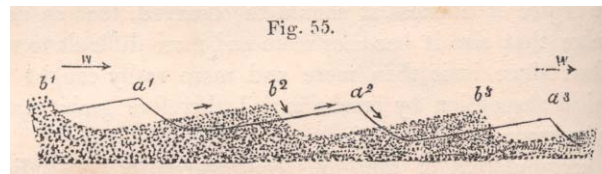


Figure 48: Movement of sand: De la Beche graphic showing directional movement, and incorporating alphabet labels. (From De la Beche, 1851a)

fathoms. Although multiple numbers were recorded, De la Beche did not take the next step and transform numbers into a true, relational graphic showing causality.

### Illustrations in Government Publications

Initially, all texts written by Henry T. De la Beche were considered as belonging to a unified publication style; likewise all articles in periodicals, chapters in edited books, and published papers were considered as a single category. Upon closer examination, however, the *reasons* for various publications were quite different, and notably diverse in some situations. In particular, some publications were authored while Henry T. De la Beche was employed by the British government as the head of the British Geological Survey, and were specifically written to address an official topic or concern. A further problem existed in the examination of official publications: Since De la Beche did have a

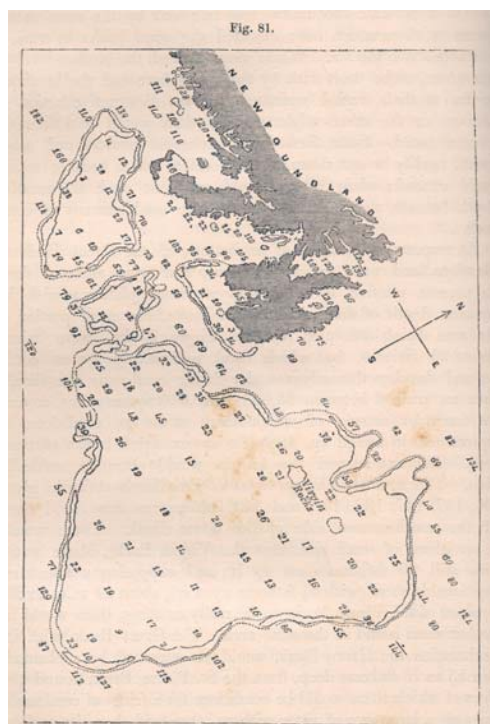


Figure 49: De la Beche incorporated numbers as data in his graphics in his last text. (From De la Beche, 1851a)

staff working under him, it is possible that he did not illustrate his official documents. Indeed, there is a suggestion from John Phillips in a letter to De la Beche that salaried artists be employed to sketch drawings of fossils (Phillips, 1842b). Although no written evidence was found to support the possibility that a salaried artist executed graphics for official publications, McKenna (personal communication, July 16, 2002) believed a professional artist was probably involved in the *Catalog of Specimens*. Sharpe (personal communication, July 11, 2002) concurred, since De la Beche had a staff when he was Director General. There were artists working under him, and he probably would have turned the graphics over to them; he did not have the time to undertake the task of illustrating later in his career, nor was he in good health. Therefore, illustrations included in government publications or for official communication were isolated into a separate

category. Appendix K presents a list of works characterized as official publications for the purpose of this research study.

Publications categorized as “official” De la Beche contributions began in 1837, and continued through 1855. However, the first two documents – an 1837 Report of the British Association for the Advancement of Science, and an 1839 Report with Reference to the Selection of Stone for Building the New Houses of Parliament – contained no graphics. These were, in fact, the only two De la Beche official publications in the Golden Age of Geology, 1788-1840. In the 1839 report, De la Beche is listed as the second author along with primary author C. Barry, William Smith, and C. H. Smith. Although bi-folding tables were included in the report, there are no proper illustrations.

The 1842 paper in the *Journal of the Agricultural Society of England* was previously included in a discussion of periodical publications; however, it was a report from De la Beche’s General Report on the Economic Geology of that district. There were no illustrations included. Likewise, the 1844 Report of the Commissioners for the Ordnance Memoir of Ireland contained no illustrations, either.

Graphics were included in the 1845 *Report on the State of Bristol, Bath, Frome, Swansea, Merthyr Tydfil, and Brecon, England*. Data were often included in the report in tabular form, and three colored plates were inserted as well. The first plate was a colored map of Bristol; it depicts geological formations, the common seats of Feber, and the cholera cases in 1832. This multivariate map is shown in Figure 50. The third plate is also a map, in this case of Bath, England. Plate two portrayed sectional views, and incorporated a scale as well as direct labels.

The 1846 paper in the *Memoirs of the Geological Survey of Great Britain* included over 40 wood engravings. However, the illustrations were of mixed quality.

Some of the lower quality graphics were heavily inked, while some better graphics did show directionality, as well as inferences. The most common additions to illustrations were again alphabet labels.

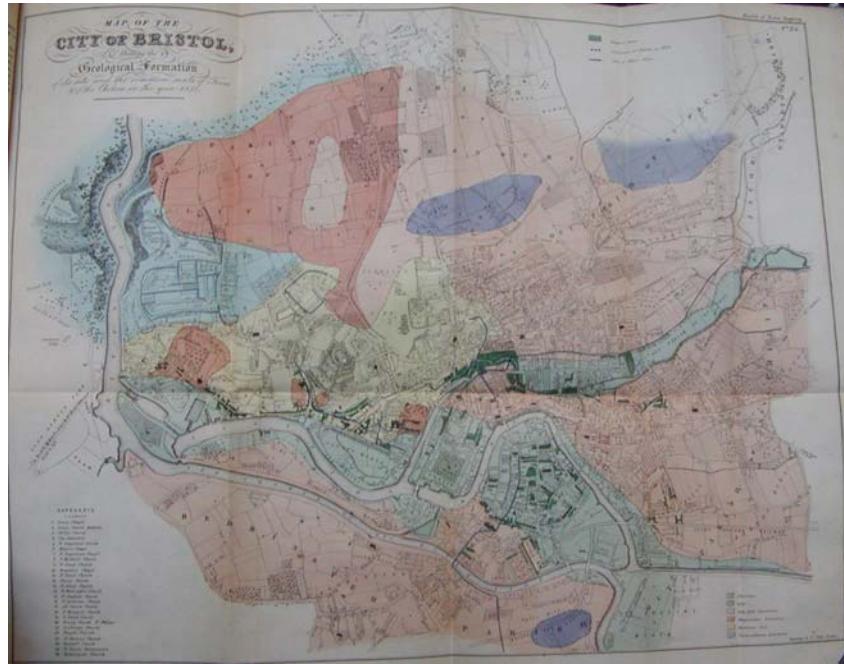


Figure 50: Photograph of a multivariate map of Bristol, showing the geological formations, cholera occurrence, and common seats of Feber. (From De la Beche, 1845b)

De la Beche co-authored several works with Lyon Playfair, including the 1847 *Gases and Explosions in Collieries*, and the first, second, and third reports on the coal suited for the steam navy. If a distinction is made between *scientific* and *technological* publications, then the De la Beche and Playfair contributions were definitely in the realm of technology. The *First Report on the Coals Suited to the Steam Navy* is an early case of fuel research. Although it furnished a multitude of practical data for the navy, the document “wisely refrained from giving positive advice” (Bailey, 1952, p. 40).

Some of the De la Beche and Playfair papers and reports were reasonably well illustrated: The 1847 report on collieries included both wood engravings and plates, with some of the illustrations including colors, keys, scales, direct labels, and/or alphabet

labels. The 1848 *First Report on the Coals Suited to the Steam Navy* was prolific in its inclusion of mathematical equations and tables of data; it also incorporated two wood engravings of apparatus in the text, as well as five plates illustrating the schematics of equipment that were inserted behind the text. Both the *Second Report* of 1849 and the *Third Report* of 1851 continued an abundant use of mathematics and tables; however, there were no illustrations incorporated.

De la Beche wrote the chapter on mineralogy for editor Sir John Herschel's *A Manual of Scientific Enquiry, Prepared for the Use of Her Majesty's Navy, and Adapted for Travellers in General*. The 44-page chapter included seven wood engravings of laboratory equipment, sectional views, and rock types. In keeping with the usual trend for wood engraving annotations, alphabet labels were utilized.

The final official publication of Henry T. De la Beche was the 1855 *Catalogue of Specimens in the Museum of Practical Geology, Illustrative of the Composition and Manufacture of British Pottery and Porcelain, from the Occupation of Britain by the Romans to the Present Time*. Trenham Reeks, the Curator of the Museum of Practical Geology, was the co-author. The 1855 first edition of this catalog is very rare: Although copies were listed in the library catalogs of the Geological Society of London and the British Geological Survey, neither institution could locate this catalog. Therefore, an 1876 edition was examined.

The catalog includes 157 wood engravings, with the majority of the graphics pictorial in nature. While most illustrations are true proxies that represent concrete items, there are some instances when the graphics include identification in the form of alphabet labels. A typical page of ceramic examples is shown in Figure 51.

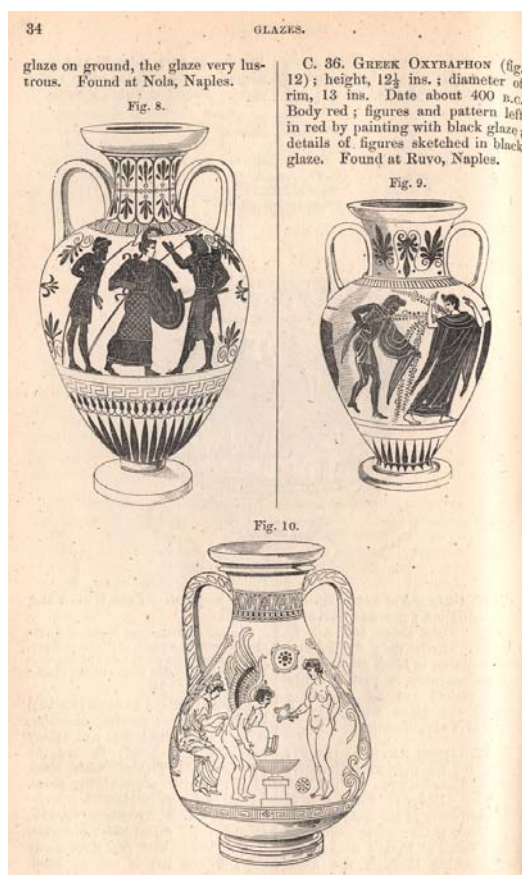


Figure 51: Three typical graphics in the *Catalogue of Specimens in the Museum of Practical Geology*. (From De la Beche & Reeks, 1876)

## Illustrations in Field Notebooks

The graphic contributions of Henry T. De la Beche to geology and geoscience education have been discussed thus far as published illustrations in periodicals, books, or government publications. However, De la Beche was truly a visual person. Not only did he include illustrations in his published papers and books, but he also embellished his journals, field notebooks, and letters with sketches and drawings. The De la Beche archives at the National Museum of Wales hold quite a few De la Beche journals and pocket diaries; I examined 13 illustrated pocket journals, diaries, and sketchbooks in the archives. The pocket journals chronicle the travels of De la Beche, beginning in November 1818, and continuing in a fairly regular sequence through June 1829. There is



also one undated sketchbook at the National Museum of Wales as well. The library of the British Geological Survey houses two early De la Beche diaries, which record his early travels from 1815 through 1817. Two other field books are part of the archives as well; although these are undated, they appear to have been composed in the early 1830s since various caricatures included at the end of a field book portray De la Beche's challenge of Lyell's theories.

The early-illustrated De la Beche diaries at the British Geological Survey immediately give the viewer an impression of a travel scrapbook, a type of pre-photographic album that predates the development of photography. An early diary (De la Beche, 1815b) only incorporated a few illustrations, with two watercolors and four sketches within the journal. However, meteorological data were interspersed, and even organized in tabular form. The watercolors were magnificent, especially when the context – the inclusion in a personal diary – is considered. In one of the watercolors, De la Beche even utilized gold leaf accents for the buttons of his Russian sailor! This picture is presented in Figure 52. The other four sketches, although rough in nature, do affirm De la Beche's early geological interest. A sketch showing the interfingering of granite is presented in Figure 53.

Another early journal in the British Geological Survey begins April 3, 1816, and is very prolific in its illustrations. It contains 75 graphics. Most are pictorial in nature, and represent true proxies of landscapes that De la Beche viewed while traveling. At first glance, the viewer is struck by how similar to souvenir snapshots many of the De la Beche illustrations are. De la Beche often included figures in the countryside sketches, and it appears as if he has placed himself in many of the scenes. This seems to be the 19th century equivalent to having one's picture taken within the landscape, or posing next





Figure 52: Colored sketch of a Russian sailor. Note the use of gold leaf accents on the buttons. (From De la Beche, 1815b)

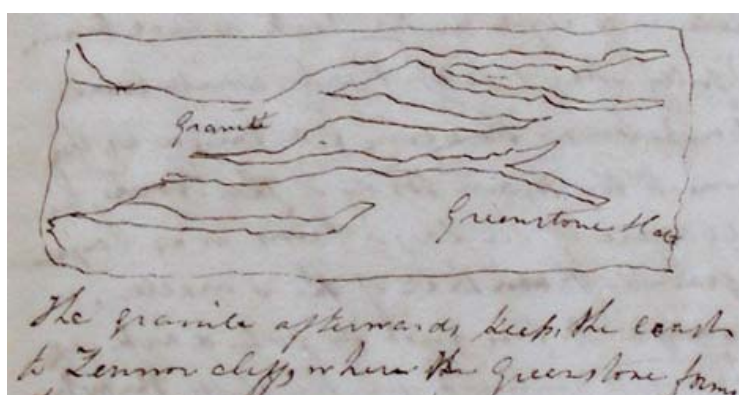


Figure 53: Early sketch by De la Beche in a personal diary. The sketch attests to De la Beche's early interest in geology. Note the use of direct labels. (From De la Beche, 1815b)

to the sign announcing a national landmark. Figure 54 presents one of the souvenir illustrations: The figure with the rock hammer, viewing the landscape, is probably none other than a self-portrayed Henry T. De la Beche.



Figure 54: Pictorial representation, or proxy, of a landscape. The figure is probably Henry T. De la Beche, holding a rock hammer. (From De la Beche, 1816)

While most of the images in the diary are monochromatic, there are a few illustrations that were composed in full color. Figure 55 shows a colored sketch of a Scottish cottage and its inhabitants. Illustrations also appear to have been completed in steps: There are graphics that have remained simple pencil sketches, while others have been altered with monochromatic paint, although they are not yet complete. De la Beche recorded his disapproval with one of his sketches with the inscription, “This is intended



Figure 55: Colored sketch from an early De la Beche diary, depicting a Scottish cottage and its inhabitants. (From De la Beche, 1815b)

to represent the principal fall of Foyers” (De la Beche, 1815b). He was obviously not satisfied with his portrayal! An incomplete sketch is shown in Figure 56. Although most



Figure 56: An incomplete sketch in an early De la Beche diary. Note the figures in the left foreground; De la Beche is probably represented. (From De la Beche, 1815b)

of the images in the early diaries are pictorial representations, there exist a few modified graphics that again point to De la Beche’s early geological interest. Figure 57 is a diagram in the text that depicts a strata relationship observed by De la Beche; the illustration included direct labeling.



Figure 57: Geological illustration in an early De la Beche diary. (From De la Beche, 1815b)

De la Beche’s illustrated pocket journals in the archives in the National Museum of Wales begin in November 1818, soon after the early diaries in the British Geological Survey end. There exists in these journals a progression in graphic sophistication from

the early diaries. Although the first journal (De la Beche, 1818) contains some pictorial representation in the 24 illustrations present, most of the graphics represent geological knowledge and observations. Fossils depictions are included, and in one case, presented as 10 figures to the page. One fossil oyster is shaded, and is presented as Figure 58.

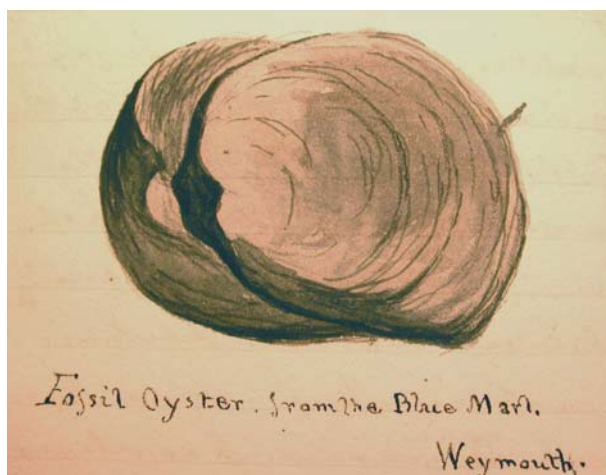


Figure 58: Shaded sketch of a fossil oyster from Weymouth. (From De la Beche, 1818)

Several sections are colored, and are presented as small multiples in some cases. Color keys are included at the bottom, and the sections are directly labeled as well. Some section sketches note the direction of dip. Figure 59 reproduces two colored sections from Ham and Osmington.

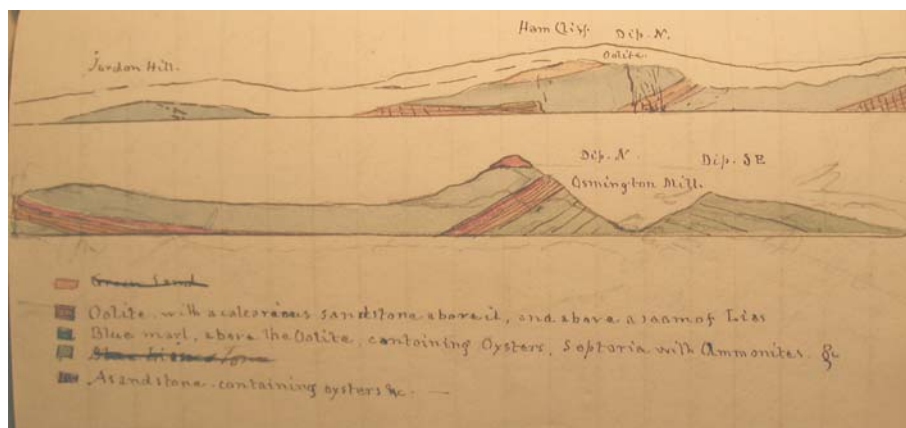


Figure 59: Two colored sections with direct labeling, and notation of dip direction. (From De la Beche, 1818)



The second pocket journal (De la Beche, 1819b) continued geological themes in the illustrations. Of the 10 included graphics, four were geological sections. There was a particularly nice representation of an anticlinal structure; this colored sketch is shown in Figure 60. This is, in fact, the earliest known geological section across the South Wales coalfield; North (1944) declared the sketch comparable to contemporary sections in elementary textbooks.

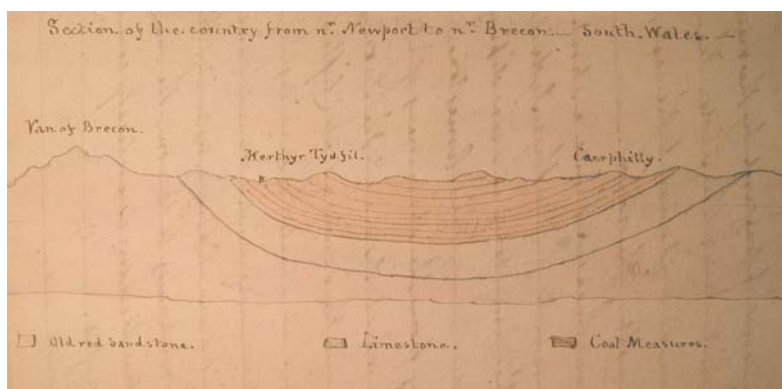


Figure 60: Anticline representation in a De la Beche pocket journal. Note the direct labels and color key. The graphic colors appear to have faded through time. (From De la Beche, 1819b)

Not all of De la Beche's pocket journals are well illustrated. Archived document 343 contained only nine images, and all were proxy sketches (De la Beche, 1819c). Likewise, archived document 344 (De la Beche, 1819d) contained nine sketches also; this journal seemed to have a lot of empty, spaced pages, as if De la Beche had intended to later draw additional illustrations, as well as finish some others. With only four sketches, archived document 345 is graphic poor; however, De la Beche had included weather observations in this pocket journal (De la Beche, 1819e).

The diary that De la Beche used while traveling in France and Switzerland in 1819 (De la Beche, 1819f) included 13 sketches. Only one of the included illustrations is a geologic sketch. However, six water colored illustrations are included, and most are particularly well done. Although these drawings seem to be too meticulously detailed to

have been composed for the sole consumption of their creator, they did supply De la Beche with an illustrated journal of his travels. These geological sketches provided visuals that could be referenced when he composed future papers and texts. It also appears likely that De la Beche could use his pocket journals to illustrate a conversation, in a similar fashion to the way a slide show or photo album is used today.

A De la Beche pocket journal of the early 1820s only included six illustrations, with two of erratic blocks, and one sectional view (De la Beche, 1820c). The March through June pocket journal of 1820 was only slightly more visual: seven illustrations were included, with three geological sketches (De la Beche, 1820a). One section of the Valley of Chamonix at the Chapeau included the lithologic identifications. One graphic was unusual; this type of visual depiction has not been seen in other De la Beche works. A stylized genealogy flow chart, showing the pedigree of Napoleon, as connected with the Faesch family of the town of Basle, was incorporated at the end of the field notebook. This is depicted in Figure 61. The final pocket journal from the 1820s held in the National Museum of Wales contained only five illustrations, none of them geological (De la Beche, 1820d).

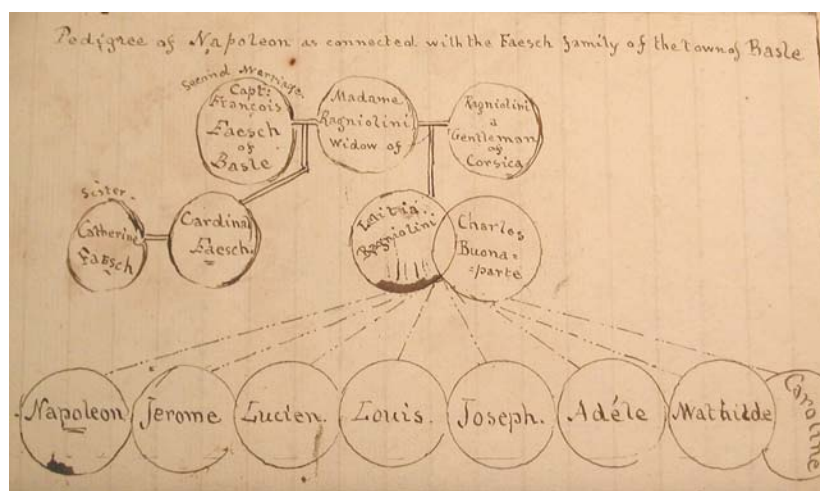


Figure 61: Pedigree of Napoleon from a De la Beche field notebook. (From De la Beche, 1820a)

A De la Beche pocket journal from 1821 contained mostly empty pages, although a couple of sketches were included at the back of the book. There were nine illustrations, all of them geological sections. Direct labeling was employed, as well as some color keys. One particular illustration supports the idea that De la Beche revisited his graphics, and improved them over time. A section that is sketched, but not colored, has a color key at the bottom. It would appear that De la Beche intended to color his graphic, but never returned to the task. This illustration is presented in Figure 62.

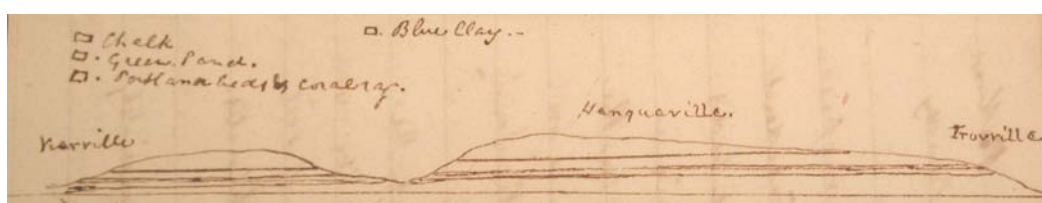


Figure 62: Section in progress. Note the color key at the bottom of the sketch, but the absence of color. (From De la Beche, 1821)

The pocket journals used during the Jamaican travels were not abundantly illustrated (De la Beche, 1823a, 1823b). The first diary contained an accumulation of numbers as data, but incorporated very few graphic representations. Only five sketches appear within the diary, and these sketches are fairly rough in quality. The extended Jamaican journal did not have any sketches.

One prolifically illustrated diary emerged in archive 363: The journal that De la Beche utilized during his journeys in Italy contains over 70 illustrations, many geological in nature. As in previous journals, the graphics are in varying stages of completion, and are of varying quality. Some spaces were left empty, as if in allocation for sketches, but De la Beche never returned to complete them. Included in the diary are geological sections, machinery, and pictorial images of landscapes and people. There are also a few caricatures. Direct labels, color keys, and annotations were employed with some of the graphics. It appears that many of the included illustrations have more information

labeled on the sketch than in previous journals. For example, Figure 63 presents a colored section with direct labels and compass directions, while Figure 64 reproduces three landscape views that are identified through numbers. A key is included at the bottom of the illustration.

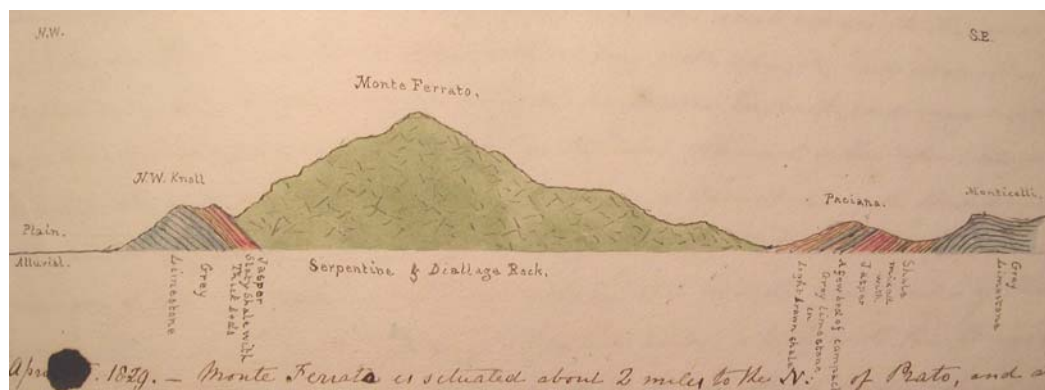


Figure 63: Sectional view in a De la Beche notebook, colored with direct labels (including lithologies) and compass directions. (From De la Beche, 1828)

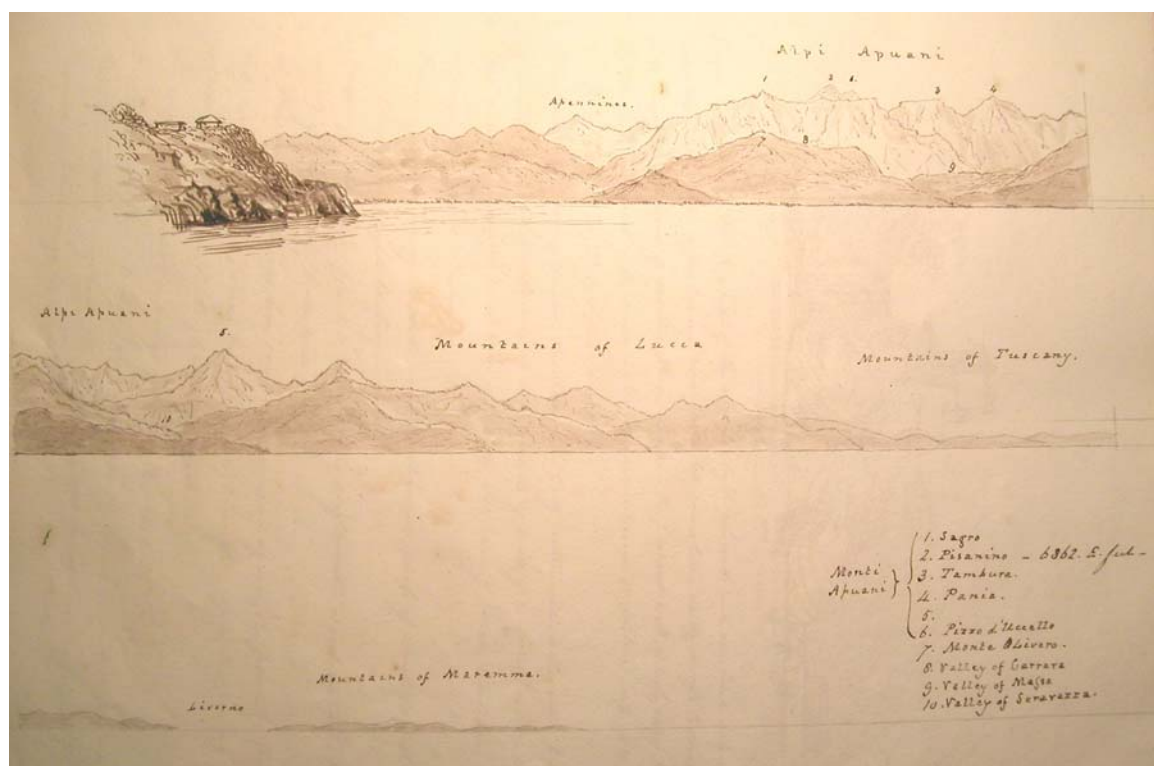


Figure 64: Three landscape views. Note the numbering of different features, and the included key in the lower right corner. (From De la Beche, 1828)



The final sketchbook examined in the National Museum of Wales is not dated, and includes only a few completed illustrations. Many potential illustrations are only roughed into place. The completed sections do employ coloring and direct labels; some sections are spread across two pages in the sketchbook (De la Beche, n.d.-i).

The most recent De la Beche notebooks and sketchbooks that were investigated were those in the British Geological Survey; they probably date to the early 1830s. GMS 1/123 is a treasure trove of caricatures criticizing Lyell's grand theories of geology; however, it also includes over 20 sketches and geological sections, some colored, and some with direct labels and/or alphabet labels (De la Beche, circa 1830b). There was even a page with labeled sections that were discussed under "Geological Terms." Also, De la Beche sometimes sketched his sections within a landscape view. Figure 65 reproduces one of these illustrations. The other later field notebook within the British Geological Survey is graphic-poor, however. De la Beche verbally described geological sections, and noted exact measurements, but he did not translate the verbal and mathematical data into visual portrayals.

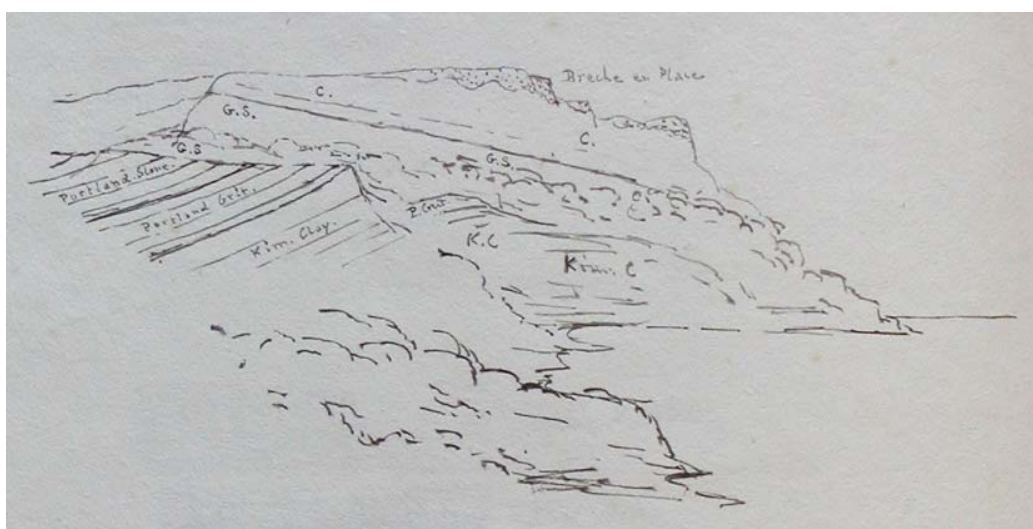


Figure 65: Sketch of a geological section within a landscape, in a de la Beche field notebook. Note the direct labeling. (From De la Beche, circa 1830b)



Society of London and the British Geological Survey are sketches of ichthyosaurs and belemnites that appear to have been destined for some of the early De la Beche journal articles (De la Beche, circa 1821, 1825d). The De la Beche collection in the National Museum of Wales also has sketches intended for later publication: An ink sketch of miners was noted to be the sketch for Plate 6, “Part of the interior Fowey Consols Copper Mine” (De la Beche, 1839a), while two other graphics were later incorporated in the 1851 *The Geological Observer* (De la Beche, 1851b).

There are some drawings contained in the examined archives that do not appear to have obvious connections to later published material. The National Museum of Wales has more than a few De la Beche sketches that illustrate a variety of scenes. Included in the archives are geological sketches (De la Beche, n.d.-g), leaf rubbings and portraits (De la Beche, n.d.-b), landscapes (De la Beche, n.d.-f), and a sketch for a horse engine (De la Beche, n.d.-e). Some of the De la Beche archived graphics are more artistic than scientific. For example, a painting of Zennor Cliff held in the Geological Society of London archives is a pictorial representation. There are no annotations or direct labels, but two figures are included in the scene, perhaps to provide scale (De la Beche, 1815a). At the bottom of the painting is noted, “Presented to the Geological Society by H. T. De la Beche, Esq. M.G.S.” This watercolor is shown in Figure 67. Other archived paintings in the Geological Society of London were also noted as having been presented by De la Beche, including a painting of the submarine forest at Stolford (De la Beche, n.d.-d). De la Beche also drew an interesting, although rough, sketch of a Geological Society of London meeting (De la Beche, 1830d). The most interesting painting in the Geological Society of London archives, however, is an unusual picture of an ichthyosaur (De la Beche, 1834a). The ichthyosaur was painted with fossil sepia, and is shown in Figure 68.



Figure 67: Painting of Zennor Cliff. Note the figures in the sketch, perhaps used for scale. (De la Beche, 1815a)

Goodhue (2002) discussed the role that Mary Anning played in the discovery of the fossil ink of belemnites: Anning carefully sawed open a belemnite fossil and discovered a tiny chamber, containing what appeared to be dried ink. She hypothesized that the belemnites employed a similar defense mechanism as the modern sea hares, which expelled purple ink in order to hide from predators. Since tourists visited Lyme Regis to purchase the



Figure 68: Picture of an ichthyosaur painted with fossil sepia. The sepia was recovered from belemnite fossils, and was used to paint pictures of extinct life from the area. (From De la Beche, 1834a)

fossils recovered from the Lias cliffs, it was not long before the belemnites' fossil sepia was reconstituted and used to paint pictures of their extinct contemporaries; these pictures also became a sales item for the visitors to the area (Torrens, 1995). It appears that Henry De la Beche, a long-time acquaintance of Mary Anning, also tried to paint with the fossilized ink.

Another loose De la Beche graphic is interesting because of a comment written by Mary Anning. On the back of a sketch of a geological section is written, "This section of White Chapel Pinney Cliffs was made by H. T. De la Beach," and the signature "Mary Anning" follows (De la Beche, n.d.-h). This graphic is reproduced in Figure 69.

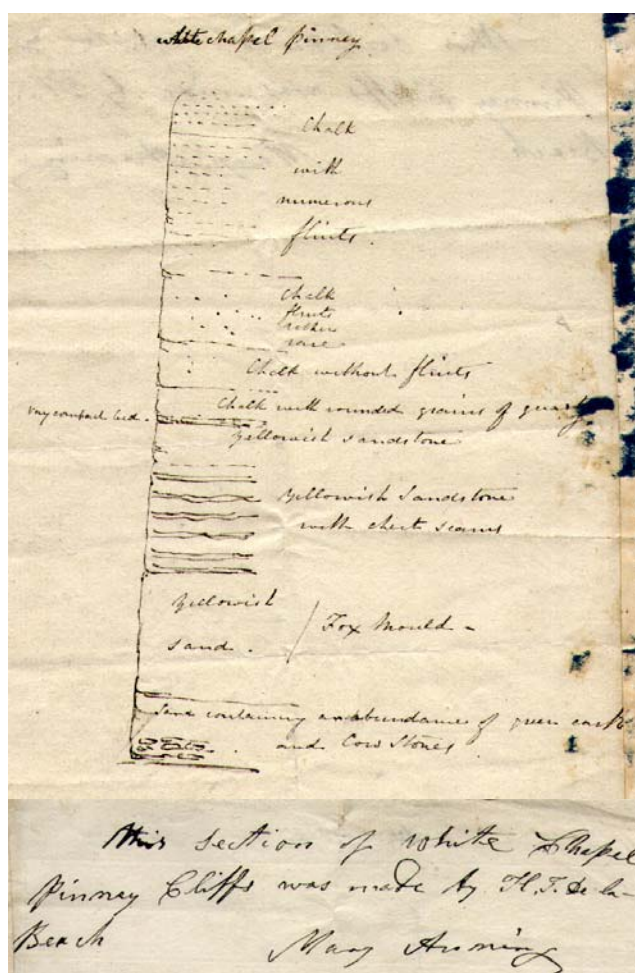


Figure 69: Sectional sketch by Henry T. De la Beche. A note written by Mary Anning on the reverse side is shown at the bottom. (From De la Beche, n.d.-h)

**Maps.** Henry T. De la Beche was perhaps best known among his contemporaries for producing items of utility. As the first Director General of what was to eventually become the British Geological Survey, he was in charge of geologically mapping the British countryside, and depicting the data as geological maps. However, these were not the first geological maps he produced. Three early maps are listed in Sharpe and McCartney's (1998) De la Beche publication list: a map of 24 miles around the city of Bath, a map of Lac Lémon printed in Geneva, and a tabular and proportional view of the superior, supermedial and medial rocks.

The British Geological Survey holds a copy of the geological map of Bath. The map is typical in that direct labels are present, as well as a scale and a latitude and longitude grid. The geological data have been superimposed over the map as colored formations, and a color key is displayed on the left hand side. This map was not the sole effort of De la Beche; William Conybeare is given credit for the map's production as the first author. A photograph of this 1823 map is shown as Figure 70.

Another published map, *A Tabular and Proportional View of the Superior, Supermedial, and Medial Rocks (Tertiary and Secondary Rocks)*, is a colored proportional section, presented as a large foldout map, and backed with linen. The rocks' and fossils' characteristics are included as annotations.

Other maps attributed to De la Beche, including re-worked maps, are held in the various archives in the United Kingdom. For example, a beautifully colored geological map of Weymouth is held in the Geological Society of London (De la Beche, 1830c). The map is backed with canvas, with the edges framed with cloth seam binding. The colors are wonderfully vivid, especially when the viewer considers the map is over 130 years old. A geologically colored map, sectional views, and vertical sections are



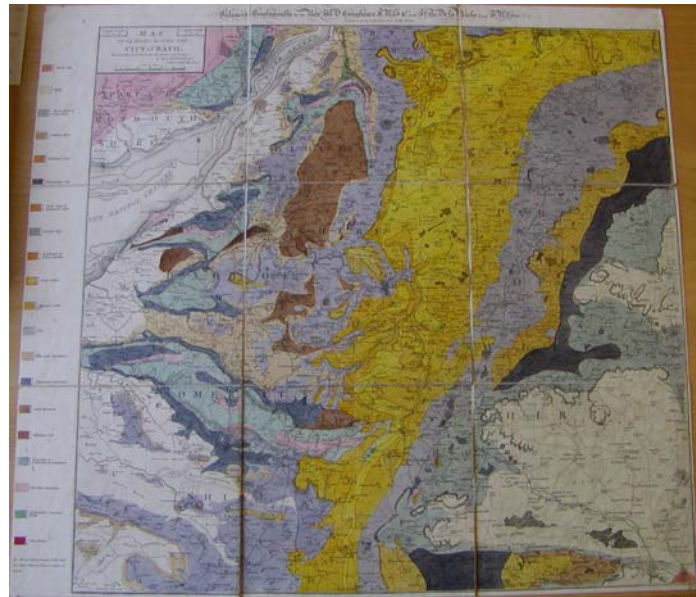


Figure 70: Geological map of Bath. (From Conybeare & De la Beche, 1823)

presented. The color key is at the bottom. Although De la Beche did not create the original ordinance map, he did color it and add the sections and descriptions for his 1835 paper, co-authored with William Buckland. The Geological Society of London also houses another small map attributed to De la Beche. This unarchived map is titled the Geological Map of the Environs of Lyme Regis; it includes colored formations with a color key, direct labels, and the annotation, “The lias of this coast contains a great abundance and variety of Organic Remains.” Another handwritten annotation states that the scale is one inch for every one mile.

De la Beche maps are included in the archives of the National Museum of Wales as well. A geological map of the Gulf of Spezia is a work in progress, with visible grid lines that De la Beche utilized in the drawing process (De la Beche, n.d.-a). A working map of the Geological Survey of England has the map divided into quadrants, with pink coloration indicating that the areas have been geologically analyzed and published. The sections are numbered, with a number key off to the left (De la Beche, 1838c). This is a

fine example of a working graphic that easily depicts the progress of the geological survey. A photo of this annotated map is shown in Figure 71.

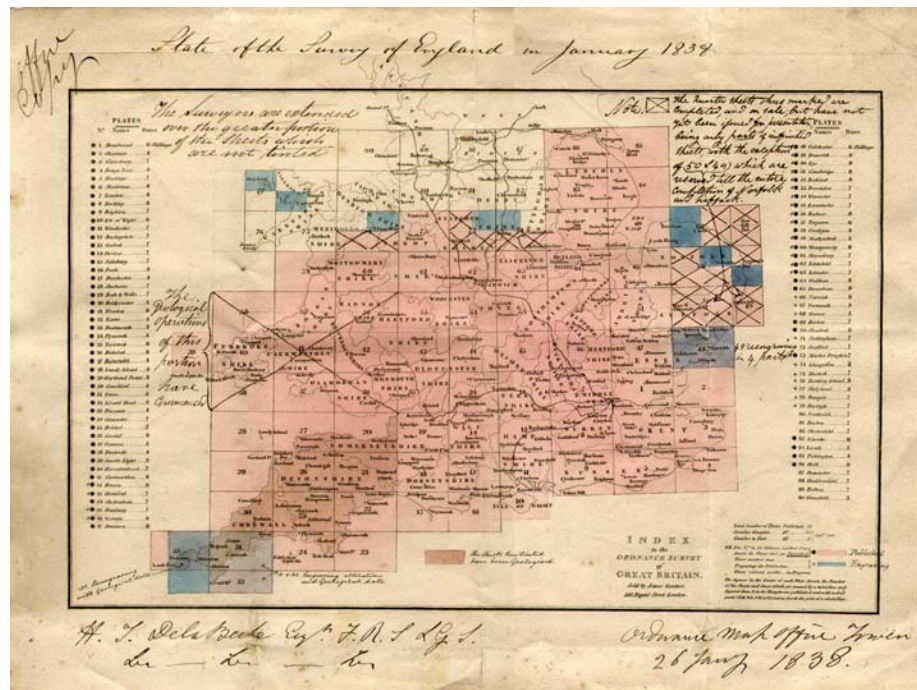


Figure 71: State of the Survey of England in January 1838. (From De la Beche, 1838c)

Another De la Beche working map is held at the British Geological Survey as an unarchived map. This was De la Beche's personal map of Devon, and the map has been modified with colors, presumably to indicate the geology that De la Beche ascertained through his fieldwork. De la Beche also added a sectional view across the very top of the map; the sectional view portrays not only the geology of the section, but also presents the topography as well (De la Beche, n.d.-c). In addition, De la Beche added a small watercolor sketch in the upper left corner of the map. Graham McKenna (personal communication, July 15, 2002) noted that the watercolor sketch was similar to pictorial representations found on maritime charts, which give a sectional view of what the harbor looks like as a vessel approaches. McKenna (personal communication, July 16, 2002) also stated that the De la Beche's sketch of the cave entrance is analogous in format to



the photographs chosen today to illustrate the outside covers of memoirs for publication.

A close-up view of this sketch is shown in Figure 72.

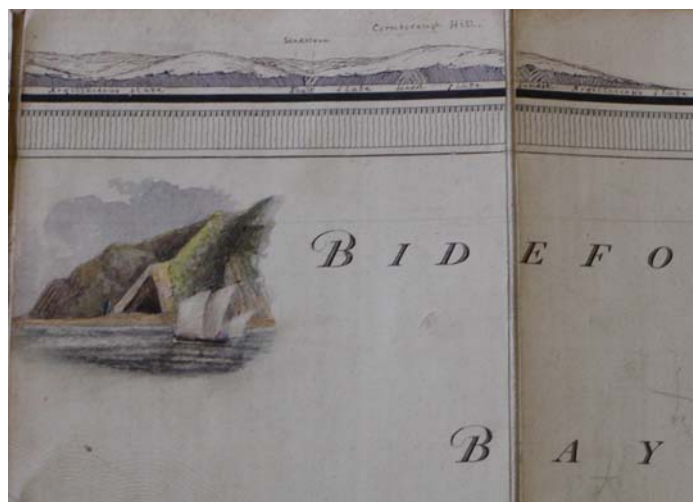


Figure 72: A working map in which De la Beche has added a sectional view at the top, and a sketch of a landscape feature of the area. (From De la Beche, n.d.-c)

**Lithographs.** Lithographs published as individual graphics were much more important to visual imaging than prints are today. Without moving images of television and video games, people of the 19th century collected individual prints, and had them framed for display on their walls or catalogued in portfolios for later viewing. This static library of the 1800s is comparable to the video libraries that people collect today (Rudwick, personal communication, July 3, 2002). Therefore, it is not unusual that De la Beche graphics that were printed individually would be more *artistic* than *scientific*. These individual prints are of two general types: fossil lithographs and landscape lithographs. The prints are proxies, or typical pictorial representations, and are missing additional information in the form of color keys, direct labels, or annotations.

The earliest lithographic De la Beche prints uncovered in this research investigation were dated 1817 in the Geological Society of London archives, and were prints of ichthyosaurs. One print was colored in sepia tones, and was captioned “A head

of one of the species of the Fossil Animal from the Blue Lias, Lyme Regis, Dorset. In the possession of H.T. De la Beche, Esq.” (De la Beche, 1817a). The teeth and the cracks in the fossil skull are exceptionally detailed. Another archive file in the Geological Society of London contained three paintings of ichthyosaur remains from Lyme Regis that were attributed to De la Beche. A skull, a paddle, and vertebrae ribs were all sketched and painted in shades of blue, gray, and brown (De la Beche, 1817b).

A De la Beche crocodile sketch was lithographed in 1820; three different views were portrayed (De la Beche, 1820e). Trilobite sketches were also available as individual prints; undated graphics of trilobites are preserved in the archives at the National Museum of Wales (De la Beche, n.d.-j). A trilobite print is also held in the Geological Society of London. The three trilobite figures are uncolored, and are not labeled (De la Beche, 1829e).

Fossils were not the only subjects of individual prints. A lithographed view of Jamaica was available as a very long landscape; one view was divided into two pieces. This lithograph, titled “Panoramic View from Strawberry Hill one of the St Andrews Mountains Jamaica,” was unusual in that it contained mountain identifications as subtitles. Another unusual aspect of the print was that it was signed, “Sir H. de la Beeche [*sic*]” (De la Beche, 1827a). Another landscape print by De la Beche is contained in the archives of the National Museum of Wales. The view is of an island, and areas of cultivation are visible (De la Beche, 1832a).

Most of the individual De la Beche lithographs are typical proxy images, capturing some scientific information in an artistic portrayal. However, there is one lithograph that is quite extraordinary for many reasons, including the motivation for its composition, the subject of the illustration, and the manner in which the scene is

portrayed. Without a doubt, *Duria antiquior* is one of the most important illustrations produced in the 19th century.

De la Beche drew *Duria antiquior* as a fundraiser for Mary Anning. The two met as early as 1812, when De la Beche moved to the Annings' hometown of Lyme Regis. It is probable that De la Beche's interest in geology is connected with the Annings: If the Anning family did not actually introduce De la Beche to the fossils of the region, it remains likely that their paleontological interests fostered his. De la Beche was involved in original scientific research on the ichthyosaurs and plesiosaurs whose fossils were discovered in the area. There is also mention of Mary Anning in letters to De la Beche, as well as mention of De la Beche in the annotations and letters written by Mary Anning. When Mary Anning encountered financial difficulties, it was none other than Henry T. De la Beche who came to her rescue. Using his illustrative talents, De la Beche drew a fanciful scene that reconstructed a view of the extinct animals that were collected by Mary Anning as fossils. George Scharf, a talented scientific illustrator of the time, turned De la Beche's original watercolor into a lithograph (Rudwick, 1992). The lithograph copies that were sold generated much-needed funds for Anning; the price of the lithograph – a substantial £ 2 10s – meant that only the more elite customers would probably be able to afford it (Rudwick, 1992). Rudwick (personal communication, July 3, 2002) also noted that De la Beche's act was not purely charity: The gentlemen scientists who supported projects such as these kept the fossil collector in business, and presumably would have access to more specimens as Anning continued to procure them.

The subject of *Duria antiquior* is also unusual: This is the first reconstructed scene from deep time that was published, even with limited circulation. Although Georges Cuvier attempted reconstructions of soft anatomy of various extinct animals, the

sketches were not published during his lifetime (Rudwick, 1997). De la Beche recreated the extinct animals based on the scientific knowledge of the time; he managed to translate the verbal descriptions into a grand pictorial view. McCartney (1977) concurred that *Duria antiquior* was a genuine attempt to illustrate the fossils from the lower Jurassic.

The original watercolor is presented in Figure 24; however, it is also reprinted in Figure 73 for easy comparison with a lithographed version. The reconstructed animals were not just drawn in isolation by De la Beche as an exhibit; he also portrayed their *interactions* with other organisms. In the original sketch, now archived in the National Museum of Wales, a very prominent ichthyosaur is biting the neck of a plesiosaur. Another plesiosaur appears to be reaching out of the water to bite a crocodile. Still



Figure 73: *Duria antiquior*, an original watercolor by Henry T. De la Beche. The scene was drawn as a fund-raiser for Mary Anning. On the reverse side of the illustration are pencil sketches of a shark and a plesiosaur, which are probably De la Beche's instructions to the printer for changes in the graphic. (From De la Beche, circa 1830a)

another plesiosaur neck is visible in the background, as the animal has just managed to snatch a pterodactyl flying overhead. De la Beche also included the stuff of future fossils: Ichthyosaur skeletons and ammonites rest on the bottom of the sea. Rudwick (1992) eloquently noted that this conjunction of the living and dead effectively linked De la Beche's reconstructed past to the actual means by which it was recreated: The deep time illustration was based on the surviving fossils. Even the flora of the area was reconstructed with an attention to detail; De la Beche included only those plants whose fossil remains were contemporary with the fossilized remains of the animals.

Rudwick (1992) reported that the original lithograph had to be redrawn, as it was printed in greater quantities and distributed more widely. The original watercolor does have pencil sketches on the reverse of the image; these are probably De la Beche's modifications, to be noted by the printer (De la Beche, circa 1830a). The Geological Society of London has two lithographs of *Duria antiquior* in the archives, and there are some differences between these prints and the originals (De la Beche, 1837b). The British Geological Survey also has an 1837 reprint of *Duria antiquior*, originally part of Murchison's scrapbook (De la Beche, 1837a). However, Murchison's copy is colored; this appears to be the only difference between the two 1837 prints. The colored version is shown in Figure 74.

There are some obvious differences between the original watercolor and the colored 1837 version of *Duria antiquior*. For example, a plesiosaur is no longer attempting to bite a crocodile on shore; instead it attacks a sea turtle. The pencil sketch of a shark on the back of the original watercolor has been refined and included at the bottom of the print in the later version. The fish on the lower right has also changed, and now appears to be eating an arthropod. The vegetation is different as well, especially the



aquariums opened a new perspective” (Gould, 1998, p. 68). Gould also noticed in his unofficial monitoring of 19th century graphics that even after the aquarium craze began in the mid 1800s, there was not immediate acceptance for an underwater perspective; a lag time of approximately two decades preceded the common use of the aquarium view.

The employment of unusual visuals – in this instance, with both the subject matter and the viewpoint – was not usually done in conventional texts (Rudwick, 1992). When De la Beche included scenes from deep time in his second edition of *A Geological Manual*, he reverted to the traditional, above-the-water viewpoint. This is not to say, however, that the lithograph was not scientifically received: Buckland used *Duria antiquior* for teaching his classes at Oxford, and remarked to De la Beche in a letter that “I have a capital class which I am sure is 30 per cent better off for your *Duria Antiquior* by way of a syllabus” (Buckland, 1831a). A later letter by Buckland to De la Beche, dated May 25, 1831, also praised *Duria antiquior* and stated, “I have a capital class and your *Duria* has contributed to its numbers and my entertainment of them” (Buckland, 1831b). It appears, therefore, that De la Beche’s *Duria antiquior* was the first innovative geology teaching graphic. Buckland later wrote to De la Beche when he learned of a German parody of *Duria antiquior*, and asked (“begged”) De la Beche to draw two or three other restorations from deep time (Buckland, 1831c). Buckland’s suggestions for future scenes included the period “immediately preceding the formation of Diluvium – a Land Piece,” a lake scene, and a sea scene of the Carboniferous. For some unknown reason, De la Beche never acted upon Buckland’s suggestion. Perhaps this conversation between De la Beche and Buckland is one of the first recorded interactions among geologists that concerned geology education.

De la Beche's *Duria antiquior* did become quite famous, however; Rudwick (1992) reported that the fame of the lithograph allowed De la Beche to use the animal figures for a very different purpose. When Lyell (1830/1991) claimed that the history of the earth was cyclical, rather than directional toward the present day, many geologists, including De la Beche, found the idea preposterous. In order to garner support for his position, De la Beche produced an imaginative scene from the future as a caricature.

### **Caricatures**

De la Beche's illustrative innovations did not end with the exceptional *Duria antiquior*. Although an "unofficial" graphic form, De la Beche managed to persuade and influence his colleagues through the use of caricatures – pictorial forms that deliberately exaggerated certain features and peculiarities. Caricatures started to appear in De la Beche's field notebooks in 1828, and it was not too much later that De la Beche began to copy and distribute them among his colleagues. De la Beche continued his use of caricatures, at least through the 1840s.

Some of the earliest De la Beche caricatures are contained in a diary held in the archives at the National Museum of Wales (De la Beche, 1828). The sketches do not involve geological issues, but instead offer commentaries on social and religious matters. For example, one of the included sketches was apparently De la Beche's commentary on the human vanity. Entitled "Taking a Cameo Portrait," this caricature is presented in Figure 75. Although the caricatures drawn in the diary were not reproduced, their attention and level to detail leads one to suspect that they were not intended only as an outlet for De la Beche's creative abilities. It seems plausible that De la Beche might have taken out his diary among his friends, and exhibited both the pictorial representations of his travels, and his commentaries in the form of caricatures.





Figure 75: Caricature drawn in a De la Beche diary, commenting on man's vanity. (From De la Beche, 1828)

It was not long before De la Beche applied his thematic cartooning skills to geological issues. The first caricature uncovered in this research study that deals specifically with a geological subject is “A Coprolitic Vision,” published circa 1829. Buckland investigated the fossilized feces – or coprolites, as he termed them – of several animals preserved in the Lyme Regis area, many of which were collected by Mary Anning. Buckland had even read a paper on ichthyosaur coprolites from Lyme Regis early in 1829 (McCartney, 1977). De la Beche apparently found the subject humorous, and responded with a bawdy caricature. Figure 23 reproduces this caricature, which McCartney (1977) rightly noted, “conceals considerable scientific accomplishments beneath flippant humour” (p. 48).

Buckland and De la Beche were friends, however, and the purpose of “A Coprolitic Vision” was probably intended mainly for humor. However, as Leddy (1981) insightfully remarked, De la Beche's caricatures are “well suited to communicate subtleties of relationships, personalities and attitudes which played an important role at a

time when geology lacked a strictly scientific code” (p. 38). It was not long before De la Beche turned his caricature skills toward a new person – Charles Lyell – and with a new purpose. Rudwick (1975) analyzed sketches in De la Beche’s field notebook that were probably compiled between 1830 and 1831 (De la Beche, circa 1830b). He convincingly argued that the sketches were aimed toward questioning Lyell’s recently published *Principles of Geology*, with one of the sketches being a definite precursor for “Awful Changes,” a caricature that attacked Lyell’s non-directional evolution for earth history. It also appears that De la Beche drew an even earlier caricature; William Buckland thanked him for his “caricature of Actual Causes” in an 1830 letter (Buckland, 1830). Rudwick (1975) believed that the sketches in the field notebook represented De la Beche’s experimentation to find a suitable theme for a Lyellian theory attack.

Caricature sketches in the field notebook in the British Geological Survey appear to broadly fall into five separate themes, in a slight modification of Rudwick’s (1975) thorough analysis. There are those caricatures that directly attack the promoter of theory, who is characterized as ignoring facts by selectively viewing through tinted spectacles. A second theme criticizes the presumed grandiosity of the newly published text. The third theme highlights the dubious rise and fall of the ocean level, while a fourth theme grandly illustrates the difference between the accepted catastrophic view, and the uniformitarian view promoted by Lyell. The fifth theme – and the one that eventually was made available through publication – criticizes Lyell’s belief in a circular, non-directional view of earth history.

The theme De la Beche experimented with most is the first, which is the proposal of theory via selective acknowledgement of the facts. Three sketches appear to be variations upon this theme, and either employ for the observer tinted glasses to mask a

complete view of the facts exposed by the earth, or an eye patch partially occluding the viewer's vision. Figure 76 reproduces one of these caricatures, in which a gentleman (Lyell) is offering a field geologist (De la Beche) some tinted spectacles in order that he might be able to see more clearly. The implication is clear: De la Beche is attacking Lyell's presumptuousness in proposing a grand scheme when he has not bothered to investigate the facts in the field.



Figure 76: A caricature sketch on one of De la Beche's five lines of Lyellian attack: De la Beche criticized Lyell for proposing grandiose theories while selectively ignoring the facts garnered through observation. (From De la Beche, circa 1830b).

De la Beche also sketched a caricature, and a small "vignette" caricature, in response to Lyell's pomposity in presuming his text was a unifying explanation for geology. In one small sketch, a book – presumably Lyell's *Principles* – is being lifted through wings and a hot air balloon. De la Beche's commentary may be that the book's position was not justified, and attained its current status only through the use of hot air, or

unsubstantiated claims. A more direct attack is seen in Figure 77, which has a book-bearing man approaching Father Time and an amorphous shape, presumably representing Space. The human is audacious in his imperative to these superhuman characters, “Behold my book, Sirs, Time & Space.” De la Beche also managed to incorporate the tinted spectacles, presumably to symbolize selective viewing, from his first theme.



Figure 77: Caricature from De la Beche’s field notebook, in which he attacks Lyell’s pompous assumption that his book provides the unifying theory of time and space. (From De la Beche, circa 1830b)

The third obvious theme challenges Lyell’s hypothesis of crustal blocks oscillating in dynamic equilibrium (Rudwick, 1975). De la Beche experimented with two caricatures, both involving a scale in which the continents are balanced. In one scene, Father Time, again wearing tinted glasses, holds the scale in which America is balanced against Europe and Africa. The other sketch, also balancing the same continents on the scale, depicts winged creatures that are utilized in weighting and lifting the continents to maintain the correct sea level.

The fourth theme of De la Beche's experimentation is the battle between catastrophism and uniformitarianism. The one sketch of this theme is shown in Figure 78. Diluvium, the deposits presumably left by ancient catastrophic floods, are challenged by Alluvium, the deposits and erosional features carved through millennia of running water. Three geologists, rock hammers in hand, are perched atop Diluvium. When De la Beche's challenge to Buckland's diluvium hypothesis is considered (Buckland, 1829; De la Beche 1829a), the sketch might imply that the geologists were slowly chipping away, or eroding, the concept. Alluvium is appropriately represented as Father Time, although he has gained wings and spectacles in this scene. It appears that Alluvium is attacking Diluvium, although there is perhaps the implication that the attack should not be considered seriously, since Alluvium has a clouded perception, and needs the assistance of wings.

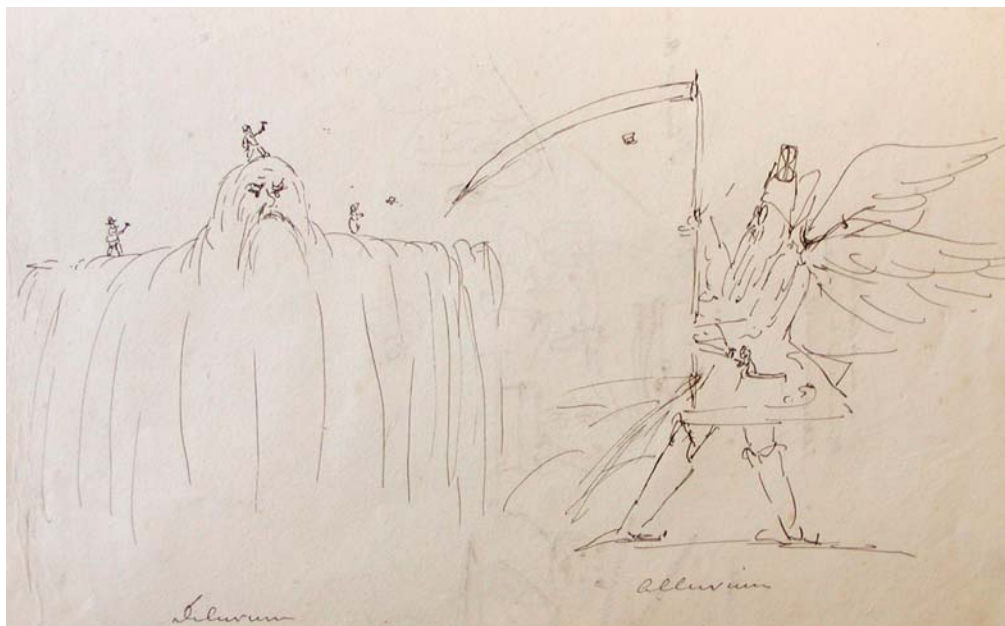


Figure 78: A spectacled and winged Father Time represents uniformitarianism's Alluvium, which is challenging catastrophism's Diluvium. Note the geologists chipping away on Diluvium. (From De la Beche, circa 1830b)

The last theme in De la Beche's caricature sketches attacks Lyell's view of nondirectional evolution for earth history. These two sketches employ anthropomorphic

figures of ichthyosaurs and plesiosaurs; these extinct animals were eventually incorporated into the published caricature, “Awful Changes.” Rudwick (1975) effectively argued that one of the sketches was a definite precursor to “Awful Changes,” and the Professor Ichthyosaurus in the graphic should be identified as Lyell. This sketch is presented in Figure 79. A comparison of the final “Awful Changes” lithograph (Figure 22) with Figure 79 confirms Rudwick’s claims. De la Beche undoubtedly used the extinct animals to illustrate what he thought was a ridiculous assumption by Lyell. The fossil record indicated a directional path toward the present, and Lyell had ignored the facts of the fossil record when he claimed that animals of the past might one day re-evolve in the future.

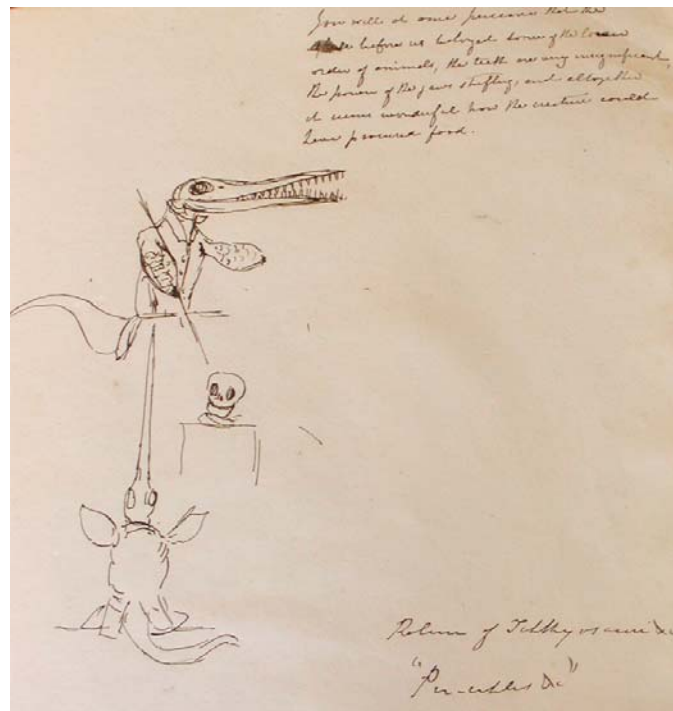


Figure 79: Sketch from De la Beche’s field notebook, and a definite precursor to the caricature “Awful Changes.” (From De la Beche, circa 1830b)

Rudwick (1975) believed that the sketches were all preliminary experiments, and were eventually finalized into the one caricature “Awful Changes.” Yet, it is not

altogether improbable that De la Beche did show his sketches to other geologists; he may have very well sought other opinions before settling on the final lithographed caricature of “Awful Changes.” However, there is no evidence to confirm this suspicion.

“Awful Changes” expanded the theme from the sketch in De la Beche’s field notebook; many plesiosaurs and ichthyosaurs are in rapt attention to Professor Ichthyosaurus’ lecture on the trifling nature of the human skull. It has not been determined how many copies of the caricature were printed, nor how it was distributed. Rudwick (1992) believed that the caricature’s circulation was limited to the elite circle of gentlemen geologists. The National Museum of Wales does have 25 copies of the caricature; this was De la Beche’s original supply (De la Beche, 1830a). Sharpe (personal communication, July 11, 2002) believed that De la Beche originally might have printed 50 to 100 of the caricatures.

It is interesting to note that De la Beche’s field notebook contained more than just caricatures reflecting the geological controversies of the time. Social and religious commentaries were included as well. A particularly insightful glimpse into De la Beche’s frustration in the field can be seen in Figure 80. De la Beche’s geological equipment is on the table, his rucksack is hung on a chair, and yet he is kept inside with inclement weather. The caption reads, “Opportunity to study the effects of rain on glass.” The expression on his face reveals his dissatisfaction with the scenario! An 1842 letter from John Phillips raises an interesting possibility that De la Beche may have reproduced another, similar caricature on this theme. Phillips (1842a) stated, “Thank you for the funny sketch, the only funny thing about the rain which has wetted everything but me.”

The sketches in the field notebook, and the resulting “Awful Changes” were not the only caricatures directed against Lyell’s *Principals of Geology*. Neville Haile (1997)





Figure 80: Caricature in a De la Beche field notebook, capturing De la Beche's frustration at being indoors. (From De la Beche, circa 1830b)

discussed a “piddling” caricature done by De la Beche, in which De la Beche attacks Lyell’s belief that large valleys could result from the small streams that now traversed them. De la Beche drew Frank Buckland, son of William Buckland, urinating in a large valley. The comment by the boy’s nurse is “Bless the baby! What a Walley he has a-made!!!” Entitled “Cause and Effect,” the caricature was probably produced some time between 1830 and 1833. The copy in Figure 81 is in Buckland’s papers at the Oxford University Museum of Natural History. However, Buckland was not the only geologist to whom the caricature was shown; Murchison remarked on the caricature in a letter to De la Beche 20 years later (Haile, 1997). Although uniformitarianism has been ultimately accepted in geological circles, De la Beche was correct in believing that a small stream, such as the one shown in the caricature, could not produce the large



U-shaped valley. Today, geologists recognize past glaciations as responsible for many large valleys with “ill-fitting” streams.



Figure 81: De la Beche’s caricature challenging Lyell’s belief that rivers in valleys were responsible for the erosional features of the valley. Although Lyell’s uniformitarianism is accepted today, De la Beche was correct in noting that the river depicted above was not responsible for the U-shaped valley. (From De la Beche, circa 1830-1833)

Although many of De la Beche’s scientific caricatures reflected his opinions of Charles Lyell’s theories, some caricatures comment on other scientific matters.

McCartney (1977) discussed an 1832 caricature, “The Light of Science,” in which De la Beche has portrayed a woman with a lantern illuminating the earth (Figure 82). The caption, “The light of science dispelling the darkness which covered the world,” is an obvious comment on De la Beche’s belief in the advancement of science. Another caricature, “A Philosophical Lecture,” portrays a smiling De la Beche among less-than-positive contemporaries. This caricature was drawn in a copy of *Geological Manual*, which had blank pages inserted between the pages for editor comments; it is shown in Figure 83.

In 1834, De la Beche was just entering into what was eventually to be known as the Devonian controversy. When Greenough read De la Beche’s letter to the Geological

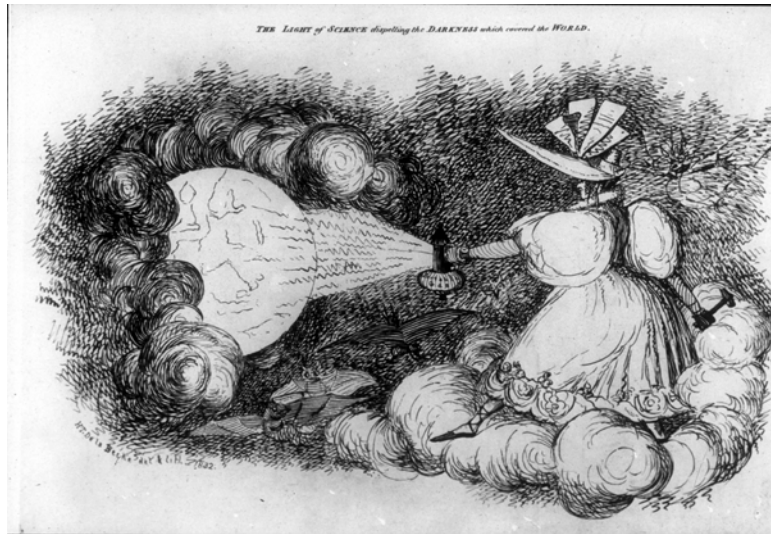


Figure 82: De la Beche's caricature, "Light of Science."  
(From a slide copy from the National Museum of Wales, Cardiff)



Figure 83: A smiling De la Beche, presumably  
among his geological contemporaries. (From  
De la Beche, 1832d)

Society, Murchison and Lyell criticized De la Beche's declaration that fossils of the coal strata were found in the older transition rocks. De la Beche was employed to geologically survey the area at the time, and since his professional career – as well as his livelihood – was at risk, he tried to sway his colleagues into supporting his position. Rudwick (1985) discussed De la Beche's attempts to influence, including the caricature sent to Sedgwick, Greenough, and Turner. In the caricature, titled "Preconceived

Opinions versus Facts,” De la Beche, with a very exaggerated nose, is standing alone on the left, and is casually dressed for fieldwork. On the right, a group of five gentlemen peer at him through magnifying spectacles. De la Beche is pointing to his large proboscis, and stating, “This Gentlemen, is my *Nose*.” The gentlemen respond, “My dear fellow – your account of yourself generally may be very well, but as we have classed you, *before we saw you*, among men *without noses*, you *cannot possibly have a nose*” (Rudwick, 1985). This obviously was a not-so-subtle attempt at damage control; De la Beche’s criticism of Lyell and Murchison is thinly veiled. De la Beche maintained that if he, after spending weeks in the field analyzing the geology, reported his factual observations, then it was entirely inconceivable that Lyell and Murchison, who had not spent time in the field and analyzed the area, were correct in their opinions, based simply on their pronouncements that their opinions were valid.

In 1837, De la Beche created a parody report, *The Mining Chronicle*, in which he drew a caricature on Robert Were Fox’s experiments on the magnetism and temperature in mines (McCartney, 1977). In De la Beche’s “experiment,” temperature within the mine is determined by the amount of clothing retained by miners, who are positioned along a rope at different levels of the mine. The humor is evident in the parody; although the “experiment” is unscientific, De la Beche noted a control of variables in his discussion. Each miner was placed at regular intervals, and each miner was initially clothed in the same manner. Since the lower miners retain less of their clothing, the temperature must increase within mines! De la Beche further noted, “We cannot sufficiently admire this beautiful experiment, proper repetitions of which must lead to the most extended views” (De la Beche, 1837d) “Heat in Mines” is shown in Figure 84.

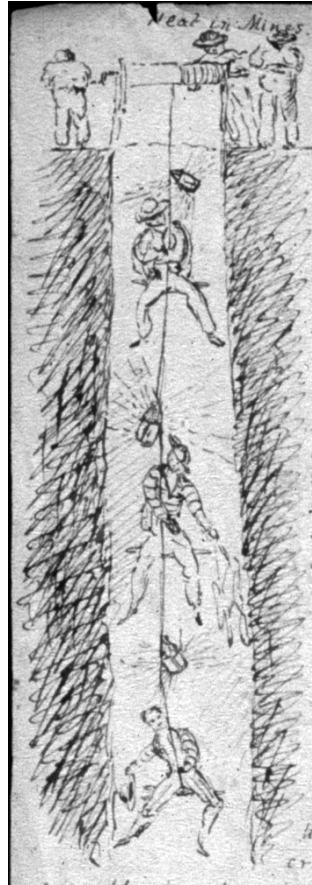


Figure 84: De la Beche's caricature spoofing Fox's experiments on the heat in mines. (From De la Beche 1837d).

The latest caricature penned by De la Beche that was uncovered in this research investigation is “Irregularities of Sol.” De la Beche sketched this while in Cardiff in 1841, following the recent proposal of glacial theory. Louis Agassiz proposed that glaciers had traversed the landscape in the past where they no longer exist today; their past existence could be inferred by the geological features they had left behind. Although Buckland and Lyell were soon supporters of the theory, many in the elite geological circles thought it absurd. De la Beche, who elevated *facts* above *theories*, did not join the supporting glacial ranks when so few factual examples were evident. He drew the caricature, pictured in Figure 85, as a commentary on his position. The surprised figure on the left, gazing at the scene, appears to be a self-portrayed De la Beche. Three

anthropomorphic simians are in the foreground; McCartney (1977) presumed these figures to be Buckland, Agassiz, and Lyell. One of the sun's eyes is covered with an eye patch, and the reduced radiation seemingly furthered the glaciers depicted in the right background. As Mr. Sol's wavering effects are reflected in the earth's landscape, rains fall on the tropical scene. In all probability, a transformation from tropical climate to arctic climate is in the making.

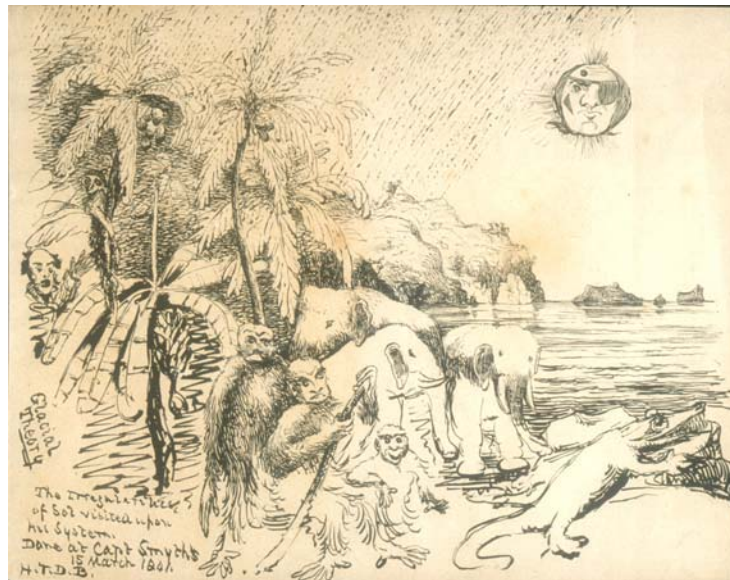


Figure 85: “Irregularities of Sol” is a caricature aimed at the glacial theory of Agassiz. De la Beche is represented as the surprised figure on the left. (From De la Beche, 1841a)

De la Beche made a least a few copies of this caricature and distributed it among his colleagues. In a letter to Buckland, De la Beche remarked with evident humor

While the other day . . . I knocked off the accompanying trifle illustrative of the sudden changes that may, according to someone, I forget who, be brought about in climate from spots on the sun. I was much too pushed for time to finish the affair, but if you will put your hand upon the lower parts of the elephants, you will see more of the effect intended, tropical vegetables and animals bothered by snow suddenly falling because of Mr. Sol's irregularities. . . Only 20 or 25 copies of the accompanying are printed. If the Captain has already send you one, give this to Greenough for me. (De la Beche, 1841b)

It appears that by 1841, De la Beche was accustomed to communicating his views on theoretical debates through the use of his caricatures. He obviously circulated these sketches in order to gather support for his position, or critique the positions of others.

### Quantitative Assessments

Henry T. De la Beche expressed facts, knowledge, and opinions through his graphics. Illustrations were obviously important to him, since they pervaded both his published and private documents. De la Beche illustrated his papers and texts, as well as his field notebooks, personal diaries, and letters. The official publications authored by him also incorporated many illustrations, although there is some question as to whether each graphic in his government publications was personally drawn by him. De la Beche was not confined to one graphic type, nor was he confined to one type of publication.

The preferred vehicle for published illustrations of Henry T. De la Beche changed throughout his lifetime. Figure 86 plots the number of publications as periodicals, books, and government publications from 1819 through 1855. Although a simple trend does not exist, the graph does indicate that De la Beche focused firstly on periodical publications, especially in the 1820s, and then secondly moved to textbooks as a preferred medium. Although there was resurgence in periodical publications in the late 1840s, government publications became a popular format for De la Beche beginning in the mid 1840s. In order to avoid clutter on the graphic, trend lines were not depicted. However, when polynomial trend lines were calculated for each of the formats – periodicals, books, and government publications – the trend lines verified the observation. While the trend line for periodicals was negative in slope, and the trend line for government publications was positive in slope, the trend line for books was parabolic, with the vertex occurring in the mid 1830s. An overly simplified interpretation is that De la Beche began his publishing

career through periodicals, switched to the weightier text in the middle of his career, and ended his career, as the first Director General of the British Geological Survey, with his publishing focus on official government documents.

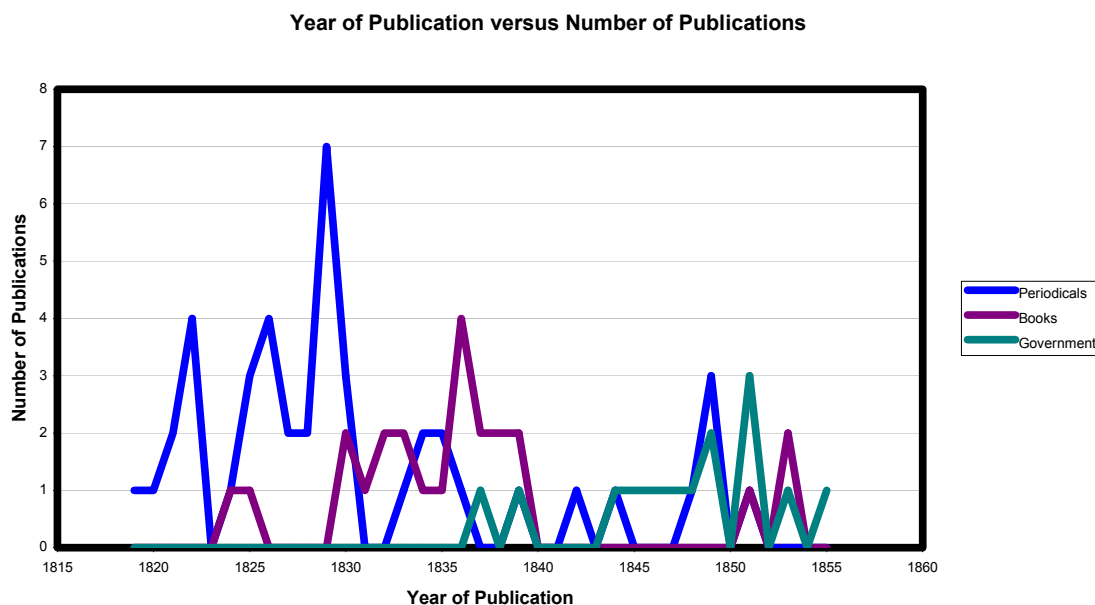


Figure 86: Graph of Henry T. De la Beche's number of publications per year, sorted by the type of publication.

The categorization and subsequent quantitative analysis of published De la Beche illustrations according to graphic type, geological content, and quality first necessitated a decision about which graphics to include. Although there is no official documentation that De la Beche ever stopped illustrating his own publications, there is a fair consensus that the pictorial representations in the government catalogs were not done by De la Beche, but by artists on staff (McKenna, personal communication, July 16, 2002; Sharpe, personal communication, July 11, 2002). As the head of the Survey in Great Britain, De la Beche's name might have also appeared on documents in which he was involved in a supervisory capacity, as opposed to a research capacity. Therefore, government

publications by De la Beche were eliminated in the detailed categorization and statistical analysis of graphics.

For periodical submissions, an author is usually bound by conventions of the journal. For example, the *Proceedings of the Geological Society of London* had as its purpose a faster transmission of information; as a result, it discouraged illustrations to fulfill this goal. An overview of the De la Beche graphics included in periodical publications also indicated that the graphics included in journal publications were very similar to those De la Beche graphics included in texts. Therefore, since it is unclear how many illustrations De la Beche provided in official publications, and since De la Beche probably had less control over his included graphics in periodical publications than he did with his published texts, a detailed analysis and categorization of graphics proceeded through only those illustrations in De la Beche's published books.

An initial investigation focused on the graphic density of De la Beche's books. Graphic density was determined by a comparison of the number of included illustrations with the total number of pages within the book; this method considered only the number of included figures, and not the area encompassed by the graphics. Wood engravings were counted as a separate figure if they were individually enumerated as a figure, or if they were inserted in the text as a separate entity, away from other figures. Some of the De la Beche books contained plates, and the difference in printing techniques between plates and wood engravings had to be considered. Therefore, an adjustment was made for the figures contained within the plates: Instead of counting the plates as individual graphics, an attempt was made to identify individual illustrations within the plates, and count these as separate figures. Graphic density was determined by the simple division of the number of total figures (determined by the addition of the total number of plate



figures and wood engravings) by the total number of pages. The data are presented in tabular form in Appendix L.

The lowest graphic density for any De la Beche book is the 1825 *Notes on the Present Conditions of the Negroes in Jamaica*. Interestingly, it is the only non-geology book in De la Beche's collection. The most illustrated text, with the highest graphic density, is the innovative *Sections and Views Illustrative of Geological Phænomena*. This 1830 text was produced so that geologists would have access to the factual representations of the data; De la Beche elevated the position of facts, represented as *visual* facts, above the position of theories. De la Beche supported “colliding theory graphics” in his text: Since each theoretical advocate needed to support his theory with facts, a good factual representation of the earth could –and more importantly, *should* – be incorporated into the various theories. A theory should explain all the earth's data, not just those examples chosen because of their support.

Since *Notes on the Present Condition of Negroes in Jamaica* and *Sections and View Illustrative of Geological Phænomena* had exceptional outlier graphic density values, these two texts were eliminated from the construction of a bar graph depicting graphic density. The other texts' graphic density is depicted in Figure 87. Whereas the earlier texts – the 1824 *Annales des Mines* translations and the 1830 *Geological Notes* – had lower graphic density, this cannot alone be attributed to De la Beche's desire or nondesire to include illustrations in the text. Illustrations were expensive, and perhaps the wood engraving process had not developed to the point to allow multiple wood engravings economically; De la Beche incorporated plates in both of these texts as opposed to wood engravings inserted within the text. Whereas the 1830 *Sections and*

*Views* was exceptionally illustrated, the text was undoubtedly expensive to print; the text is not aimed toward the general public, but toward the elite gentleman geologists.

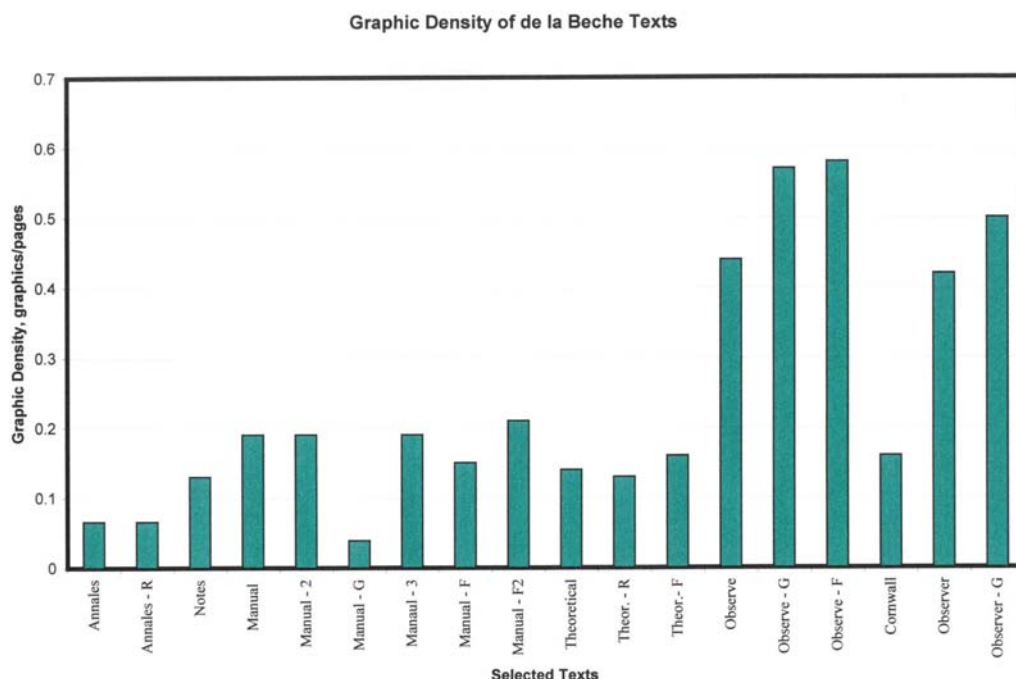


Figure 87: The graphic density of De la Beche texts, produced by dividing total number of figures included by the total number of pages. *Sections and Views* – as a high outlier value – and *Notes on the Present Condition of the Negroes in Jamaica* – as the low outlier value – were eliminated in this bar graph.

Graphic density values improve for *A Geological Manual*, except for the German edition, which eliminated many of the illustrations incorporated into the English and French versions. Ironically, graphic density fell with *Researches in Theoretical Geology* in 1834. In this text, De la Beche did not vehemently advocate one theoretical position; he maintained that positions might need to change depending upon the new facts that become available. However, he did not maintain the strong graphic density that he utilized in *A Geological Manual*.

*How to Observe Geology* and *A Geological Observer* have exceptionally high graphic density values. Between the publishing of these two texts, the *Report on the Geology of Cornwall, Devon, and West Somerset* fell to a lower graphic density value.

However, when the circumstances of the Devonian controversy are considered, the pressures De la Beche faced to maintain his aura of competence as a field geologist may have forced an early publication of the text. Illustrations may not have been deemed as important for persuasion.

The overall trend of graphic density in De la Beche's texts is one of increased use of illustrations. De la Beche incorporated many graphics in his texts, and his inclination was to include more wood engravings with each published book, if not necessarily with each reprinting of a text. Since illustrations were important to De la Beche, the next research investigated the type and quality of illustrations included, using Edward R. Tufte's theory of graphic design to develop an overall template.

Categories were first developed to characterize the graphics, in the form of quality, type, and nature of geological representation. The quality of the graphic was subdivided into its data density (low, medium, or high), the amount of chartjunk (low, medium, or high), and its multivariate nature. In addition, modifications of the graphic in terms of color, labels and/or keys, and annotations were noted. Subcategories also emerged for the type of graphic, including a simple proxy or pictorial representation, labeled proxies, inferred depictions (such as geological sections not exposed by the natural topography or road cuts), mathematical relationships, and small multiples. The nature of the geological graphics was further categorized into landscapes, maps, sections, fossils, or diagrams. The category boundaries for quality emerged only after a thorough investigation of other texts from the Golden Age of Geology. (See Chapter 6, which follows.) Therefore, De la Beche's graphic quality has materialized in comparison to other authors of the same period, and does not represent only an internal comparison

between his own texts. This was done in an attempt to standardize a qualitative assessment for quantification of data.

The graphics included in this Tufteian analysis are from all first edition De la Beche texts published during the age of focus (1788-1840), with the elimination of the non-geological text, *Notes on the Present Condition of the Negroes in Jamaica*. First editions were chosen since the illustrations in the first editions carried over to subsequent editions, with the exception of the German reprint of *A Geological Manual*. When second editions incorporated new and unique graphic forms – in the case of the French and second editions of *A Geological Manual*, which included small vignettes of deep time – the new graphics were subjected to analysis as well. However, it was discovered that the secondary editions' new graphic contributions were minute, and did not greatly influence the analysis.

It is important to remember that these categories are created, and do not represent exact groups with sharp distinctions. Furthermore, the categories represent an attempt to facilitate a comparison in an efficient way; the categories are not neat, and it is difficult to classify some graphics into one specific label. For example, some graphics could easily be categorized as a section or a diagram, depending upon whether the graphic was drawn and inferred from nature, or whether the graphic was created to illustrate a point. In general, most graphics depicting a *possible* natural scene, used for educating the viewer, are considered diagrams. However, an actual section from nature, even if used to educate the viewer, is categorized as a section. Geological sections could be inferred, or, if drawn strictly from nature, proxies or labeled proxies. It should also be realized that density and chartjunk are subjective assessments, and do not represent absolute values.

The presence or absence of trends is easily noted when the data from Appendix L are presented in small multiple format. Figure 88 presents the first of the small multiples analyses for the seven De la Beche texts examined in the age of focus; the ratio of the type of illustrations is charted for each text. Most texts had the largest percentage of their

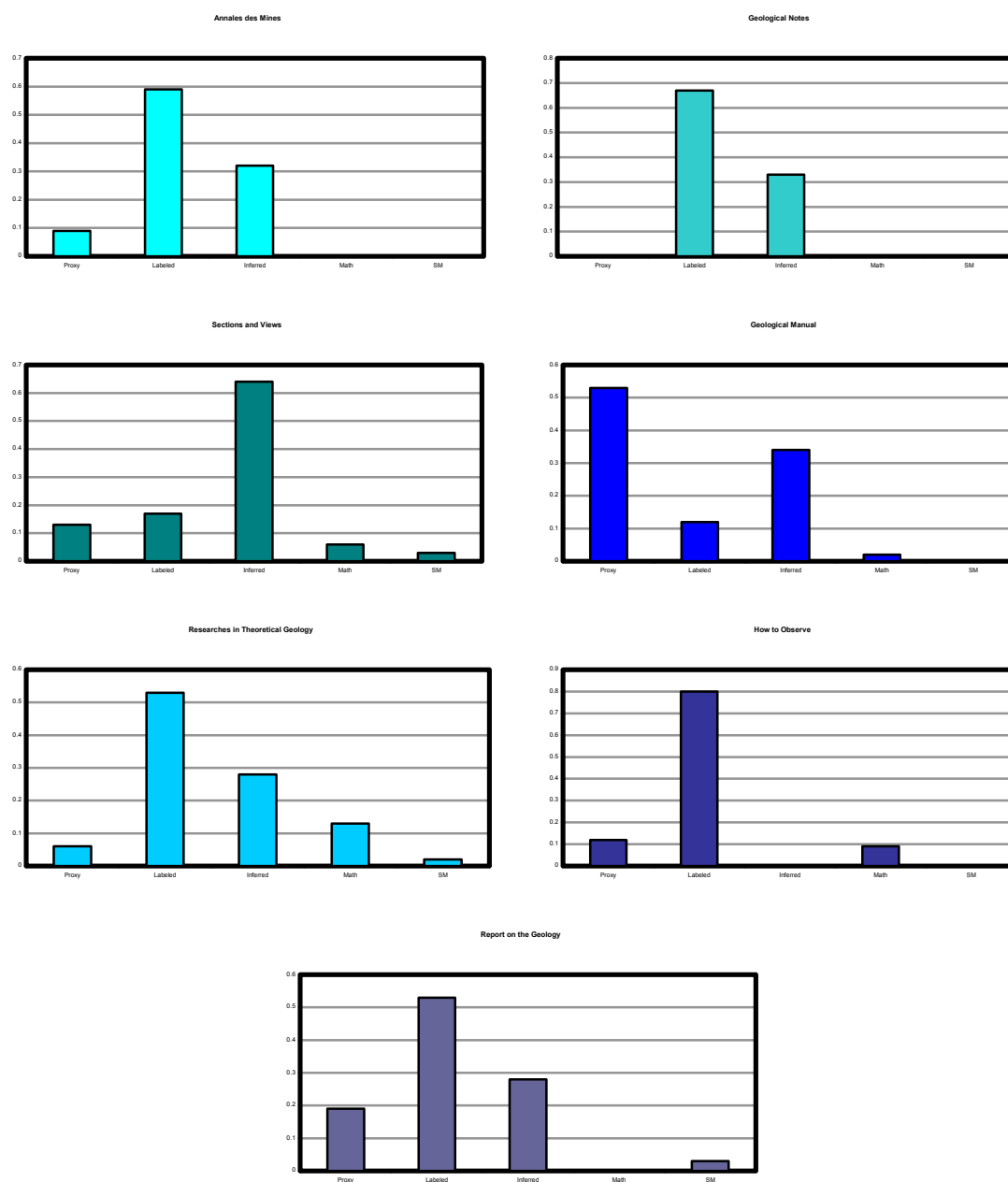


Figure 88: Small multiple graphic showing the ratio of the types of De la Beche illustrations for each text in the age of focus, 1788-1840. First columns represent pictorial representations, followed by labeled proxies, inferred graphics, mathematical graphics, and small multiples.

graphics as labeled pictorial scenes, including labeled natural scenes, objects, and events. However, *Sections and Views* was most represented by inferred graphics in the form of geological sections and inferred structure. There was also a deviation from the high role of labeled proxies in *A Geological Manual*. This was De la Beche's first text that efficiently utilized wood engravings; it incorporated more unlabeled pictorial scenes, or proxies, than any other graphic form. Many of these unlabeled proxies were in the form of fossil depictions.

The geological nature of the illustrations included in De la Beche texts is next shown in small multiple format in Figure 89. Graphics were categorized as landscapes, maps, sections, fossil depictions, or diagrams. The category boundaries overlapped a great deal when sectional scenes were drawn to portray a possibility in nature; however, since the author created these scenes, they were classified as diagrams. The most interesting trend observed in the geologic nature of De la Beche's graphics is that they moved away from depicting what was observed, and toward explaining what *could* possibly be observed. De la Beche's audience also evolved. Whereas *Sections and Views* was intended for an elite group of geologists, the later books were written more for a general reader. This is easily seen in the small multiple: Whereas the early texts incorporated more sections than any other geological item, the later texts utilized more general geology in the form of diagrams. The increased fossil depiction is also easily noted in *A Geological Manual*. It appears that Henry T. De la Beche's role became that of an *educator* as opposed to a simple observer.

The quality of De la Beche's graphics was also plotted in small multiple format to ascertain whether any trends or changes had occurred. The circle graphs in Figure 90 show the data density ratio in each text. The three texts that exhibited high data density –

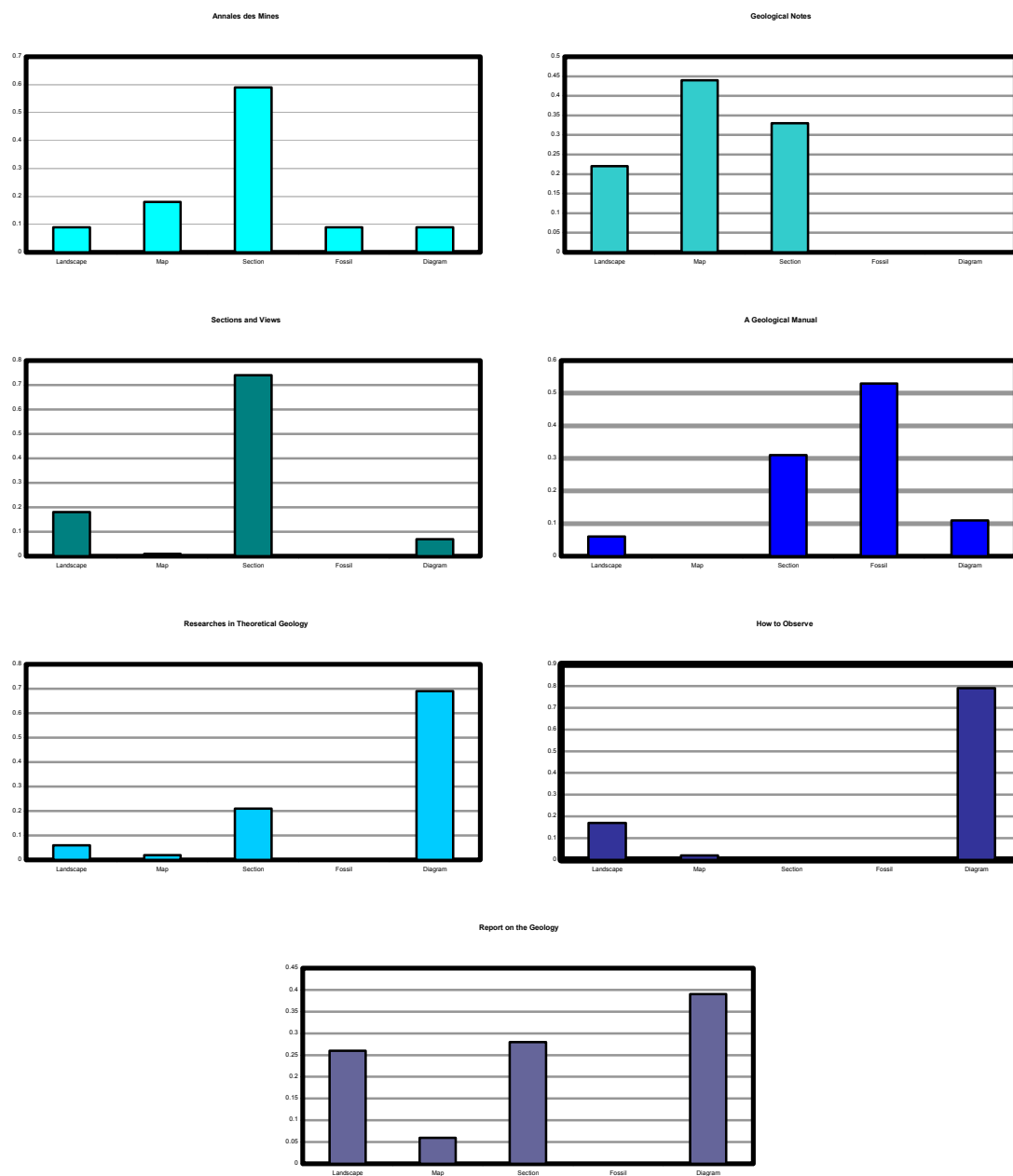


Figure 89: Small multiple graphic showing the type of geological illustration most incorporated per De la Beche text. From left, the categories are landscapes, maps, sections, fossils, and diagrams. Note the increased fossil depictions in *A Geological Manual*, second row, on right. The early use of sections and maps evolved into a more liberal use of diagrams in De la Beche's texts.

*Annales des Mines*, *Sections and Views*, and *Report on the Geology of Cornwall* – are also those texts that utilized lithographic plates instead of, or in addition to, the wood

engravings. Therefore, it appears that the vehicle of graphic display directly influences data density in De la Beche texts.

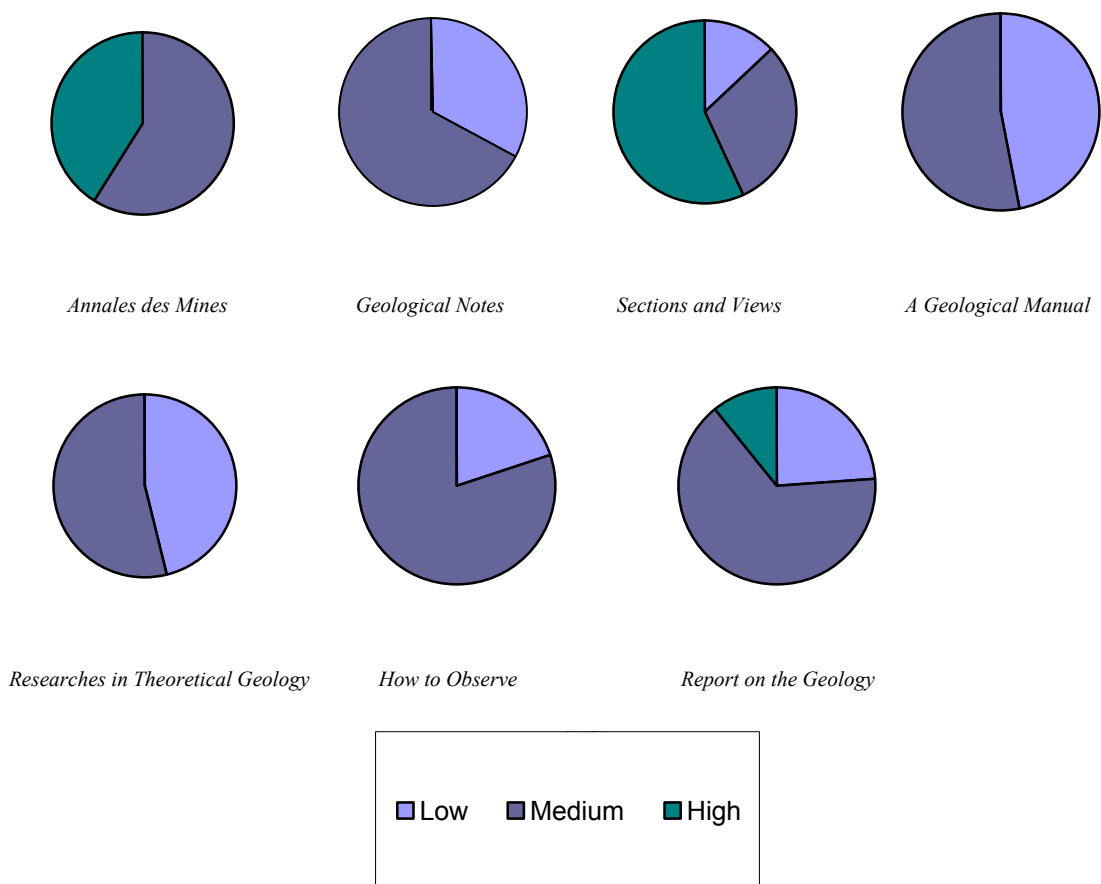


Figure 90: Data density in De la Beche texts.

Another graphical detail that was analyzed to determine quality is that variable referred to by Edward R. Tufte as “chartjunk.” Chartjunk is the unnecessary clutter that a graphic contains. In De la Beche texts, chartjunk was usually manifested in heavy, unnecessary shading or “fluff” added to the graphics that contributed nothing to the information the graphics sought to portray. Figure 91 plots low, medium, and high chartjunk ratios for each De la Beche text published in the Golden Age of Geology. There does not appear to be significant change in the amount of chartjunk incorporated into De la Beche’s graphics; the illustrations tend to be clean, with very little extraneous



ink or material. Chartjunk in De la Beche graphics tends to occur in pictorial illustrations as either the heavy use of ink or the addition of extra figures or objects.

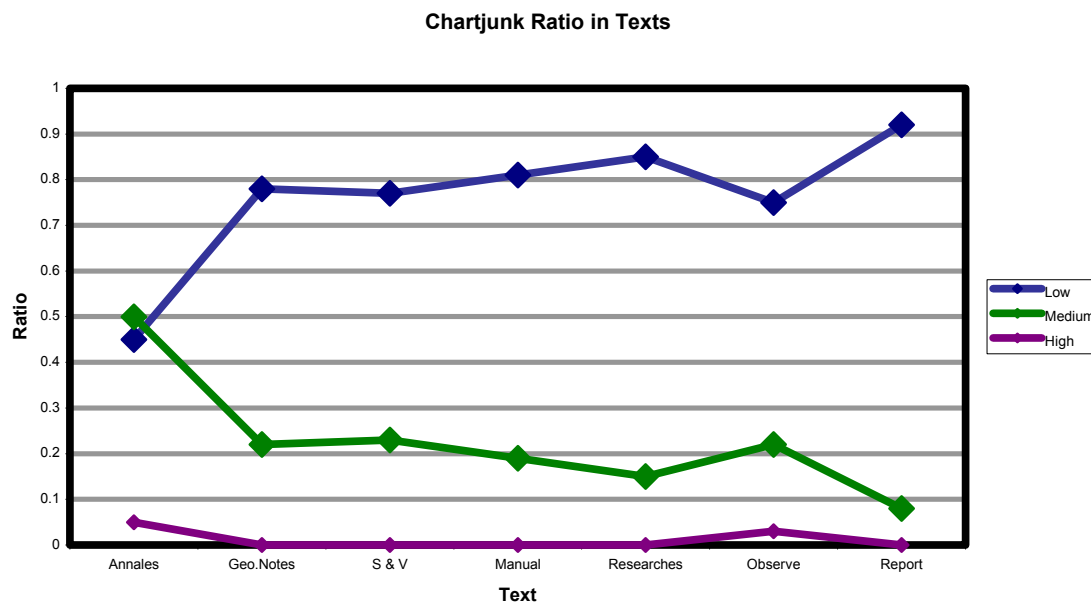


Figure 91: The amount of chartjunk in De la Beche's text illustrations, plotted as low, medium, or high ratios for each published text in the Golden Age of Geology

When the multivariate nature of the illustrations contained in De la Beche's texts is plotted for each text, Figure 92 results. The first text incorporating substantial wood engravings, *A Geological Manual*, utilized many proxy graphics depicting fossils; this resulted in the low multivariate nature of many of the figures. Graphics depicting three and four variables occurred to a greater extent in the earlier texts. However, it should not be assumed that De la Beche abandoned the more multivariate graphics in later texts. The earlier texts utilized lithographs; these allowed finer detail and could result in more information per illustration. The later texts utilized wood engravings, and beginning with *Researches in Theoretical Geology*, graphics were most often portrayed with two variables. This bivariate nature may have been partially dictated by the resolution capabilities of the wood engraving, and not the illustrator.

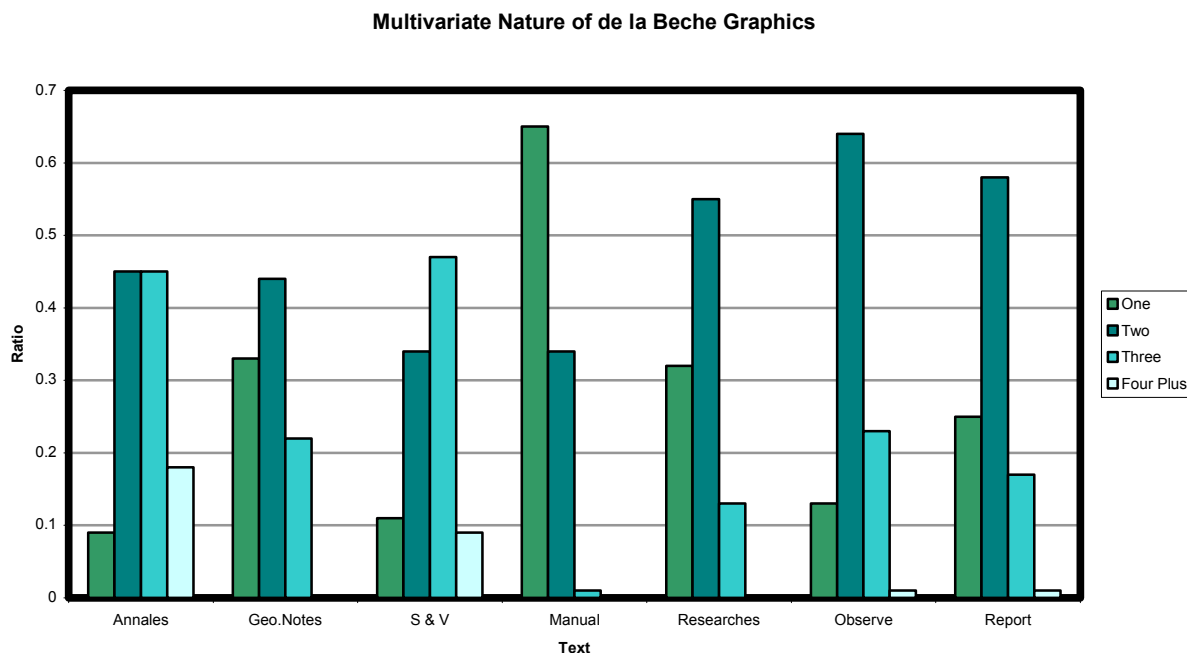


Figure 92: The multivariate nature of De la Beche's graphics in each of the texts. The ratio of the number of variables per total number of figures is plotted for each text published in the age of focus.

The final analysis of De la Beche graphics investigated the modifications to pictorial images, or the type of additional information that was added to the illustrations. These data are plotted in Figure 93. Color was not added to wood engravings within a text; therefore, the only texts that have colored illustrations are those texts that reproduced some illustrations as lithographs (*Annales des Mines*, *Sections and Views*, and *Report on the Geology of Cornwall*). Annotations also appear to be a function of the graphic medium, and are most frequently used with lithographic reproduction. Labeling, however, was a modification that was available and used with lithographs and wood engravings. Labels were used in 72% to 89% of De la Beche's graphics, with the exception of the proxy-heavy *A Geological Manual*.

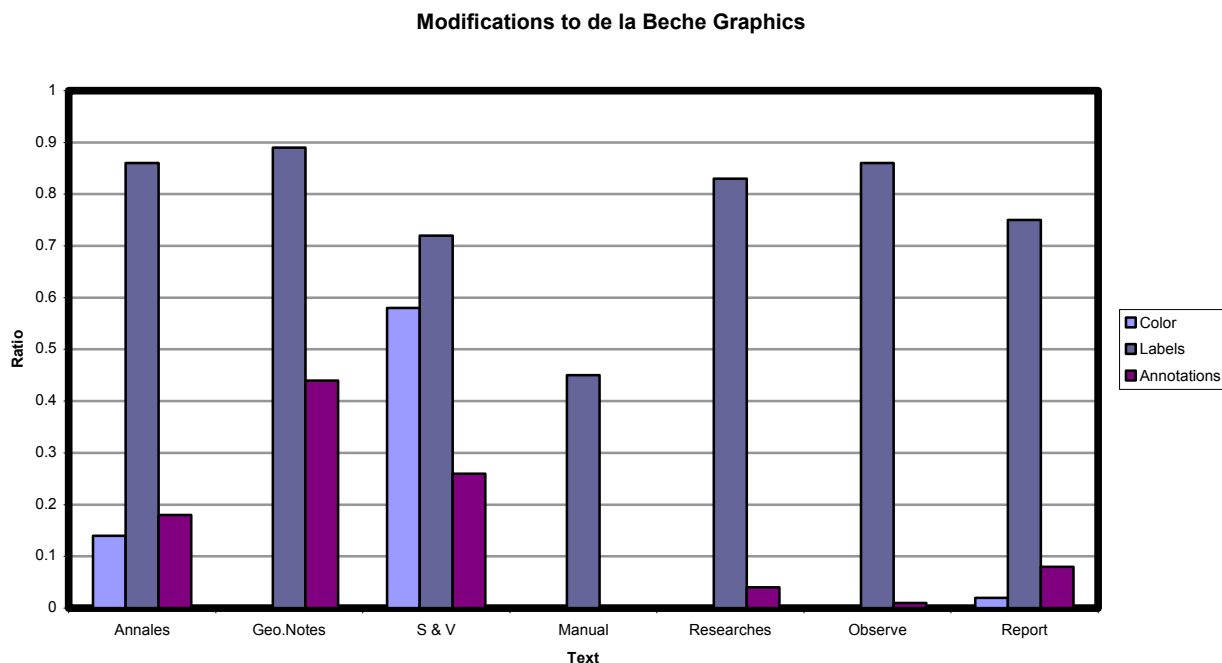


Figure 93: The ratio of modifications to De la Beche graphics for each text, in the form of color, labels, and annotations.

## Discussion

Henry T. De la Beche made many contributions to the early modern field of geology, including the design and execution of numerous illustrations that were scientific, insightful, and innovative. Unlike most geologic authors in the Golden Age of Geology, De la Beche illustrated his own publications. While it is true that many early geologists were taught how to sketch and were able to draw their observations in the field, De la Beche possessed notable artistic skill and was a better artist than most. He was able to eliminate a secondary geological illustrator in the publication of his books and articles; because of this, he had more control over his graphics than other authors within the age of focus. The visual nature of De la Beche was obvious in the published texts, articles, government documents, and lithographs. However, De la Beche's visual nature also carried over into his correspondence, field notebooks, and diaries.

The quantitative analysis of illustrations included in De la Beche texts published in the age of focus revealed certain trends. The original inferred sections that De la Beche drew from nature evolved into labeled proxies – hypothetical natural scenes – that were utilized to educate the reader. Therefore, the geological sections became generalized geological diagrams. The data density in the illustrations, and the number of variables depicted, appear to have been a function of the vehicle of representation: Whereas lithographs allowed high data density and the incorporation of more variables, the resolution of wood engravings limited the artist to fewer variables and lower density. Chartjunk tended to remain low in De la Beche graphics throughout the Golden Age of Geology. The extraneous material observed in illustrations usually occurred as either heavy shading or the addition of extra objects. Finally, the most prevalent modification or supplement to De la Beche's graphics was the addition of labels.

De la Beche's innovations in texts include the publication of small format scenes from deep time in the French edition of *A Geological Manual* (1833b). De la Beche's focus also changed in his texts: As the purpose of the text became that of general geological education, more and more of the included graphics were diagrams for instructing the reader. De la Beche's purpose of education was stated in the 1824 *Annales des Mines*; De la Beche wanted to translate geological knowledge from continental Europe to England. The purpose of the 1830 *Sections and Views* was also educative in nature: De la Beche wished to make facts known to his colleagues. Since *Sections and Views* incorporated 40 plates, the knowledge De la Beche wished to convey was done so in a visual manner. Unlike many of the elite gentlemen who theorized about geology, De la Beche did not choose persuasion as his purpose in his texts. Instead, he chose to visually present geological facts that would withstand many of the theories that

were hypothesized to explain them. The pictorial representation of facts – both obvious and inferred – eventually progressed into generalized geological representations; De la Beche created images specifically to depict certain geological phenomena for his readers. De la Beche chose to geologically *instruct* his readers. The illustrations have also retained their value in geoscience education: Although the graphics were constructed in the 1800s, they are still relevant and factual, and can easily be incorporated into geology classes today.

It is interesting to note that De la Beche was able to recognize his own effective graphics, and utilize them in different articles and books. Even as early as 1830, De la Beche was recycling some graphics from articles to books. For example, the graphic that depicted river formation in an early article in the *Philosophical Magazine and Annals of Philosophy* (1829d) was also incorporated into the book, *Geological Notes* (1830b). Many other illustrations were reprocessed from one text to another; if the graphic was not reused in its original, unadulterated form, it was only slightly modified for incorporation in a later publication.

Not all of De la Beche's graphic innovations are visible in his published texts and articles. The lithograph *Duria antiquior* was truly an artistic and scientific masterpiece within the Golden Age of Geology. This lithograph reconstructed animals only known to us from the fossils left behind; it transformed fossilized skeletal remains into an imaginative scene of living and interacting organisms. *Duria antiquior* not only illuminated deep time through a pictorial representation, it also enabled the viewer a glimpse into the ancient marine past as observed *through* the water. This viewpoint was totally novel and unique before the 1850s aquarium craze, and De la Beche possessed the creativity and artistic skill to imagine a scene and a viewpoint without prior knowledge.

The scientific caricatures drawn by De la Beche also provide the viewer with a unique glimpse into geology. Many different levels of information are encoded into these humorous graphics: The content of the geological argument is portrayed, along with the cultural and social context in which it occurred (Rudwick, 1975). The scientific caricatures further educate the viewer as to the true nature of the progression of the geological sciences. Through De la Beche's scientific caricatures, it becomes apparent that Lyell's and Agassiz's theories were not immediately accepted, but only became incorporated into the geological body of knowledge after much discussion and evidence. These scientific caricatures depict the dynamic nature of an evolving science, and avoid Duschle's (1990) final form science. Therefore, De la Beche's scientific caricatures represent a true Tufanian visual confection.

Since an absolute number of prints for a caricature is not known, it is difficult to determine the amount of influence a given scientific caricature had on the geological community at the time it was composed and circulated. However, if only 20 or 25 copies of "Irregularities of Sol" were printed, and De la Beche's implication in a letter to Buckland was that this magnitude was small (De la Beche, 1841b), it seems probable that the scientific caricatures were moderately well known among the elite geologists of England. Copies of some of De la Beche's scientific caricatures also traveled to continental Europe; letters from geologists that reference the cartoons, and copies that still survive in geological scrapbooks provide evidence for this.

When the qualitative analyses of De la Beche's graphics are integrated with the statistical analyses of the text graphics, a more complete picture of Henry T. De la Beche's graphic innovations and contributions emerges. De la Beche developed and utilized different types of illustrations throughout his geological career. The variations in

illustrations not only represent changes in the manner in which visual information was communicated, but also demonstrate the style and purpose of the graphics. Figure 94 portrays De la Beche's graphic progression in timeline format. From the timeline, the viewer can discern that De la Beche's most prolific period of graphic innovations was that period around 1830: De la Beche utilized small multiple sections (1830), created caricatures (1829), and produced the first true scene of deep time (1830). In 1831, *A Geological Manual* was published, and the wood engravings first utilized by De la Beche in an 1825 paper became prolifically utilized in a text.

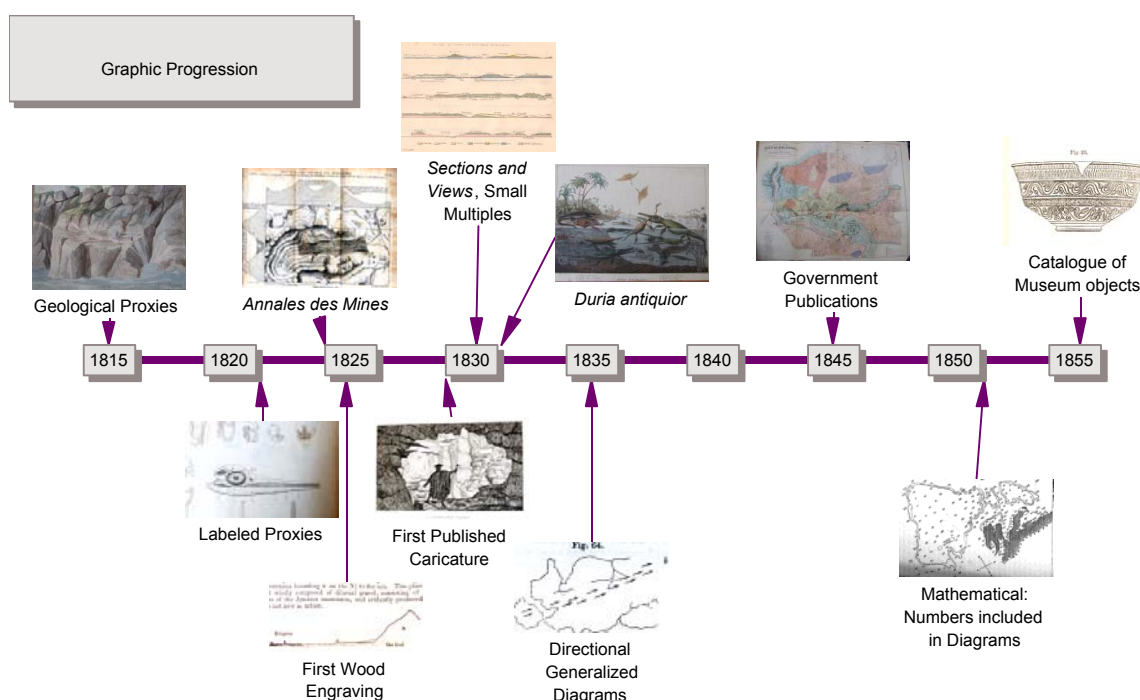


Figure 94: The timeline of Henry T. De la Beche's graphic progression.

De la Beche played an important role in the early modern science of geology, as well as in the early geological education of the general public. His caricatures, educational diagrams, and graphics from deep time were all significant contributions to both geology and geoscience education. De la Beche's purpose was also educational; he sought to enlighten his contemporaries as to the knowledge available in continental

Europe (*Annales des Mines*), and to the facts that he had observed while in the field (*Sections and Views*). De la Beche also attempted to teach general geological principles in *A Geological Manual*, *Researches in Theoretical Geology*, *How to Observe*, and *The Geological Observer*. Therefore, De la Beche was not only an outstanding geologist during the Golden Age of Geology, he was an outstanding geological educator as well.



## Chapter 6: Results and Discussion

### The Nature and Progression of Early Geological Graphics

In order to more effectively answer the main research question of the role of Henry T. De la Beche and his geology graphics in the Golden Age of Geology and their implications for geology education today, three subquestions were identified. Chapter 4 presents the investigation of the first subquestion, which is the historical context into which modern geology and its increasing dependence upon illustrations emerged. The second subquestion, or the specific graphic innovations and contributions of De la Beche, is discussed in Chapter 5. This chapter focuses on the third and final subquestion: The nature and progression of early geological graphics are examined, and the strengths and weaknesses of the graphics are revealed through analysis with Edward R. Tufte's theory of graphic design. The next chapter, Chapter 7, will summarize the research findings from the three subquestions in order to efficiently answer the main research question.

#### Graphic Trends During the Golden Age of Geology

The geosciences are very visual today in terms of their presentation: Modern geology textbooks are prolifically illustrated with photographs, diagrams, and graphs. However, the beginning texts of modern geology did not exhibit this reliance on visual presentation of data. The first publications proposing the founding theories of modern geology were those of James Hutton. The 1788 paper and the 1795 book were not only poorly illustrated by today's standards, but the selection of graphics for inclusion in the text does not appear to have been accomplished by choosing the most relevant representations. Hutton's graphics are not properly identified or cited in his text, and his choices do not seem to reflect the proposed theories that would eventually become the backbone of modern geology. By 1840, the end of this research study's focus,

illustrations in texts had evolved not only in their presentation and modifications, but also in the total number of graphics that were included in geological publications. The visual nature of geologists had become evident in their published texts, as well as in their personal correspondence.

In the beginning of the 19th century, there were two distinct areas of geological research; one was a study of specimens, as in mineralogy and paleontology, while the other study concerned the structural formations in the field (Rudwick, 1996). The two traditions appear to be in opposition; mineralogy and paleontology studied isolated samples with little context, while structural geology was an investigation of field relations, with less thought devoted to the individual examples of rocks and fossils contained in three-dimensional structure. Although the evidence provided by these two areas of geological research was hardly inclusive and comprehensive, a third specialty area of geology also existed. The grandiose theorizing about the earth sought a unifying explanation in terms of generalized models. However, in the early 1800s, the grand theorizing of geology had fallen out of favor, since many scientists were skeptical of Hutton's mammoth theories that appeared to rest on scant evidence. The accepted method of geological operation – and the method supported by Henry T. De la Beche – was the collection of facts from the earth. Facts would remain valuable long after a once-popular theory was abandoned. This fact-collecting mindset was reflected in even the earliest of texts. Bakewell (1813) discussed the affirmation of facts in the field by two trained young men, who should re-examine the “most remarkable situations described by former geologists, and . . . note down their observations on the spot. . . . [I]n the examination of dubious phenomena . . . the observations of the one might correct or confirm those of the other” (p. v.)

During the age of focus, texts were produced from the three traditions of geological research. Fossils, rocks, minerals, and structure were observed and studied, and specialized paleontology and mineralogy texts were created. While the majority of publications reflected the elevation of facts over theories, some geological authors continued to speculate grandly on unifying models of the earth. In addition, these specialty areas of geology did not necessarily exist in isolation. William Smith, Cuvier, and Brongniart all merged paleontology with stratigraphy; the text that established the stratigraphic utility of fossils was Cuvier and Brongniart's *Essai sur la Géographie Minéralogique des Environs de Paris*, initially published in 1811 (Knell, 2000).

Although geologists published in both book and journal formats in the Golden Age of Geology, the investigation of the progression of early graphics proceeds only through the early texts. This is because an overview of the published papers in the *Transactions of the Geological Society of London*, one of the major vehicles for geological publication within the period of focus, revealed that the types of illustrations included in the articles were very similar to those included in the published books. Many history of geology sources also discuss the important geological texts from 1788 through 1840; no similar identification is made for important periodical publications. Additional geology texts that were published during the age of focus were discovered in the pilot study (Appendix A); facsimiles of important geology books published by Arno Press included a list of other geology books that were likewise reproduced in facsimile versions. Sources were further identified through citations and library catalog searches, as well as through interviews and discussions with historians of geology. A modified list of texts that were investigated is presented in Appendix M. This list includes only those texts that incorporate general geological structural discussions; it eliminates the pure

paleontology and mineralogy books that were initially examined. Further, that appendix intentionally omits texts that were published before 1788 or after 1840, as well as most secondary editions and translations of a text. Although geologic texts that analyzed specific geographic areas were initially investigated, the focus during the research was the analysis of those texts that incorporated general geological knowledge.

Investigation of geology texts from 1788 through 1840, and analysis of their illustrations through Edward R. Tufte's theory of graphic design, revealed assets and limitations of early geology graphics, as well as a progression of form. A quantitative analysis of the graphics exposed any potential trends and correlations between number of illustrations and publication year. The variation of the types of illustrations with publication year was also examined.

### **Progression of Graphic Forms**

The graphics incorporated in geology texts during the Golden Age of Geology were of various types; the categorization scheme emerged in the research investigation to include proxies, labeled proxies, inferred representations, mathematical relationships, and small multiples. The illustrations were also researched as to their data density, chartjunk, multivariate properties, and graphic modification. Boundaries of the categories were established only after a thorough investigation of numerous texts; comparison between geologic graphics yielded the typical features of graphics during the age of focus. Four broad categories of graphic trends were revealed in this research investigation: 1). the early pictorial or proxy representations, 2). the emergence of labeled graphics with the first geology texts, 3). a period of grand or elaborate illustration, and 4). a period where numerous graphics were inserted within texts. The analysis of early geology illustrations

is discussed in chronological order with respect to category type; Edward R. Tufte's theory of graphic design is utilized for graphic evaluation.

**Early Publications: Reliance on Pictorial Representations.** The first graphics in published geology texts from 1788 through 1840 were the pictorial representations, or proxies, in Hutton's 1788 and 1795 publications. Both of Hutton's two plates in the 1788 paper, and the six total plates in the two published volumes of the 1795 *Theory of the Earth*, are meant to be representations of the natural scenes and objects only; no additional information is added to the illustrations. Figure 2 reproduced Plate II from the 1788 paper, while Figure 3 reproduced Plate III from Volume I of *Theory of the Earth* (1795). The pictorial illustrations appear to play the role that modern photographs do. Before a more exact reproduction of scenery and objects through photography, authors sought to insert pictorial representations in their texts with detailed lithographs and wood engravings. These proxies, however, are not necessarily accurate portrayals of the objects they supposedly represent. Monaghan (2001) warned that images of fossils should be suspect: Without a reference to type specimens, a drawing may be unreliable due to "fossil preservation, *artistic ability, scientific understanding or the politics of publication* [italics added]" (p. 90).

However, in spite of their limitations, these proxies do represent the first attempt of modern geology to establish its visual language: Latour (1990) acknowledged that no scientific discipline could exist without inventing a written and visual language, while Rudwick (1976) noted that geology's visual language helped it to achieve optical consistency. The visual language of early modern geology was in its infancy, however. The graphics are quite heavy in extraneous ink, or chartjunk, no additional information is

added, and the data density in the illustrations is low, partly because of the poor quality of the illustrative reproduction. Plate IV from Hutton's Volume I is reproduced in Figure 95.

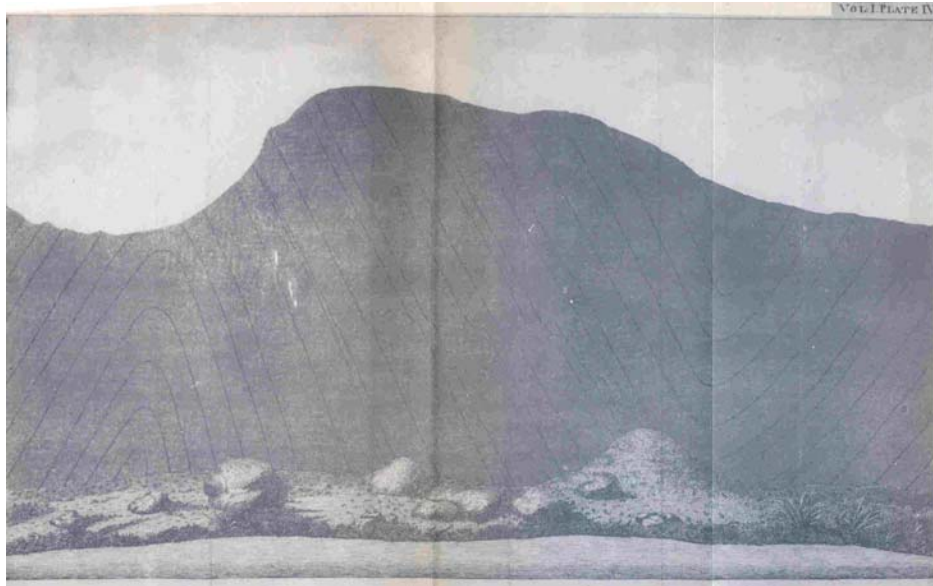


Figure 95: Plate IV from Hutton's *Theory of the Earth*, Volume I. This illustration is pictorial in nature; no additional information has been added. Note the low data density, and the excessive use of shading that qualifies as Tufian chartjunk. (From Hutton, 1795/1959)

Hutton was not the only geological author who did not utilize illustrations to their best advantage; Rudwick (1976) suggested that although geological travelers were well versed in recognizing geological topography and structure in the field, they tended to communicate their findings with words, not pictures. Since wood engravings and lithographs were not widely available as illustrative duplicating techniques until the 1820s, the graphics produced as copper engravings had to be printed separately. This fact tended to further minimize the inclusion of illustrations within texts. Many publications of the early 1800s incorporated no illustrations, including Murray (1802), Playfair (1802/1956), Lacoste (1805), De Luc (1809), Breislak (1811), Chenevix (1811), R. Smith (1812), Clinton (1815), and W. Smith (1817).

The strict reliance on a verbal method of communication changed during the Golden Age of Geology, however. Although more illustrations were incorporated into texts, many authors continued to utilize simple, pictorial representations instead of graduating to layered information on graphics. Proxies were the only included illustrations in Mease (1807); Breislak's (1818-1822) 56-plate atlas also incorporated pictorial graphics. Even though proxies represent a simplistic illustrative form, they were still utilized as graphics in geological publications throughout the Golden Age of Geology. Proxies remained an important component of included graphics in texts, even after annotations, direct labels, and alphabet identifications were added to illustrations.

**The First Geology Textbooks.** The general geological textbooks belong to a different genre altogether: The fact that a textbook is written is a presumption that the general principles of the science are established, and an audience exists which seeks instruction (Porter, 1977). After Hutton's late 18th-century publications, the new science of geology had to wait another 18 years for its first popular textbook: Bakewell's (1813) *An Introduction to Geology* attempted a general geological education of the reader. It was soon followed with many other successful geological manuals, authored by such figures as De la Beche, John Phillips, Buckland, Mantell, and Omalius d'Halloy (Woodward, 1911).

Bakewell's first textbook represents the first geological publication examined in this research study that included illustrations other than simple proxies. Bakewell's (1829) introduction stated,

The Outline Map of the Geology of England and Wales, was . . . when published in the First Edition of 1813, the only geological map of England that had then appeared. It presents in one view the grand geological divisions of the country, without delineating the different strata in each division." (p. iv)

This map, reproduced in the 1829 Bakewell version, is presented in Figure 96. The illustration represents an early example of added, or layered, information in a graphic: Colored areas represent very broad geological divisions of England, although no color key is given. The map also possesses direct labeling, numerical and alphabetical labeling, and a section with inferred information at the lower right.

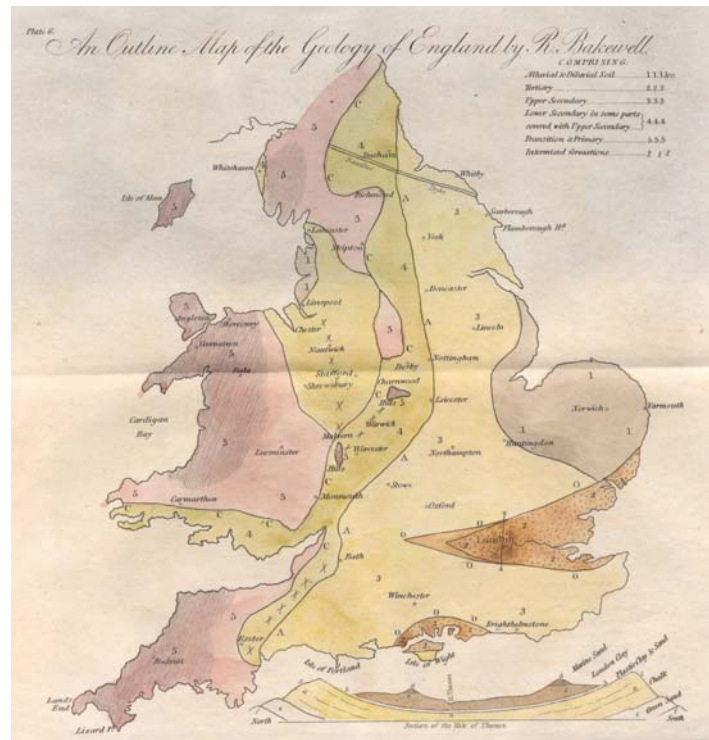


Figure 96: An early geologic map of England. The illustration is important in that it has added information to a graphic; it is a labeled proxy, and the section at the lower right is inferred from nature. (From Bakewell, 1829)

Other Bakewell illustrations in the first edition belong to the categories of proxies and labeled proxies, as well as inferred graphics. Some sections and diagrams have alphabet and direct labels, while some sections are drawn as inferred from nature. Therefore, the Bakewell (1813) text was important not only as an early geologic text, but also as an early text incorporating graphics with labeled and layered information. The addition of labels to graphics, especially with standard homogeneous scales such as



longitude, latitude, scale, strike, and dip, was an extremely important step in the evolution of geological illustrations. Standardization allowed the illustration to be transferred and translated without modifying its internal geometry; a natural image can be made flat within a text, carried to many different viewers, and reconstructed by each viewer to yield essentially the same undistorted scenario (Ivins, 1953; Latour, 1990).

Similar plates are observed in William Phillips' 1815 text. The four plates utilize coloration, but no keys are available to help the viewer decipher an unknown code. Alphabet and numerical labels are utilized in the illustrations, and some illustrations represent inferred information. However, a color key is absent, just as in the Bakewell (1813) colored illustrations. Figure 97 reproduces one of the inferred, labeled, and colored graphics in the 1815 text. Figure 98, also from the same text, is remarkable

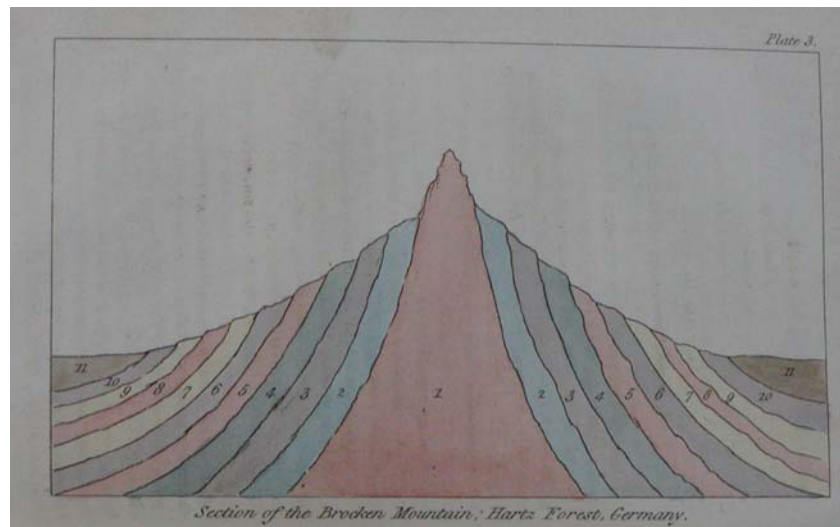


Figure 97: Section of Broken Mountain, with direct numerical labels, coloration, and inferred structure. Note the absence of the color key. (From W. Phillips, 1815).

for what it *does not* show. Although the illustration pictorially compares the height of different mountains of the world, the illustrator did not take the next step and include numerical information as annotations. Nor was any mathematical plot of the information



strata were not directly labeled on the graphic, although the successive arrangement of strata was listed on both the left and right sides of the foldout. There were no numbers or letters used for identification, but either could have been easily employed.

Greenough (1819/1978) included only one graphic within his text. It was simplistic in style, utilized direct labeling, and minimized chartjunk. Texts also existed that included no graphics: Surprisingly, French anatomist and paleontologist Georges Cuvier included no illustrations in an early essay (Cuvier, 1819). Von Buch (1820) also utilized no pictorial representations in his text.

The first illustration color key located in this research study was that in Aubuisson de Voisins (1819) *Traité de Géognosie*. Three sections are presented in the graphic, with the color key located off to the left. Tufte (1990) advocated the use of colors found in nature, especially those of lighter tones. Small differences in hues, as long as they are discernable, are desired. It is also important to remember that although the brain does acknowledge a natural hierarchy for gray tones, there is no similar ordering of the spectrum. However, viewers have become indoctrinated to certain color representations in graphics; most viewers automatically recognize that a deeper hue of blue represents deeper water in a bathymetric map. The use of color in graphics in the early 1800s was not a precise art, and quality control over color application was dubious. Since the illustrations were colored by hand, obvious differences from one graphic to another exist.

The use of color in Aubuisson de Voisins' (1819) illustration breaks many of Tufte's rules of graphic excellence. The colors are very dark, and very hard to distinguish in some cases. The graphic also employs an unusual labeling: There are three sections in the illustration, but within each section, individual figure numbers are included above certain features. A photograph of the illustration is shown as Figure 99.

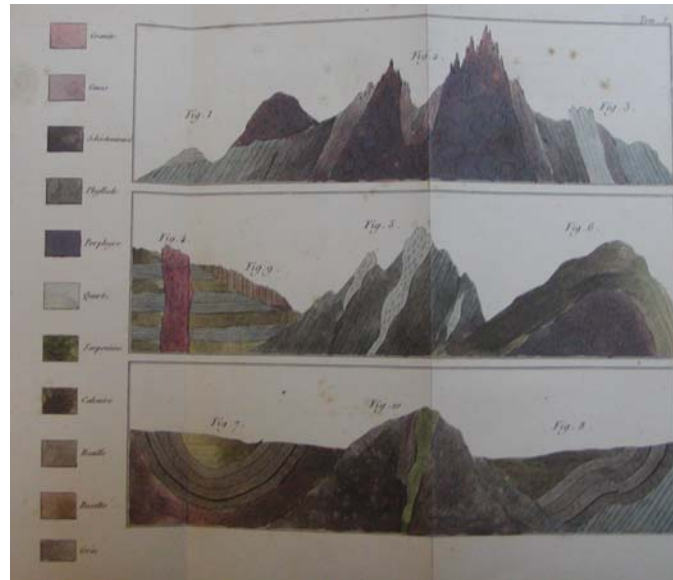


Figure 99: An early example of a geological graphic that includes a color key. Note that the colors are very dark, and often hard to distinguish. The three individual sections also have figure numbers above various features. (From Aubuisson de Voisins, 1819).

Aubuisson de Voisins reprinted *Traité de Géognosie* in 1828. It is difficult to hypothesize whether the author or publisher recognized a problem in the use of color in the 1819 text, and whether he sought to correct it. However, the fact remains that the color use in the 1828 version is noticeably different for the same graphic. The 1828 plate is shown in Figure 100.

In addition to the early use of a color key, the 1819 Aubuisson de Voisins text also included another unusual illustration: Plate II in Volume II included direct labels of lithologies and place names on the graphic, and also employed a scale along the side. The scale is unusual in that most geological illustrations of this period incorporated no numerical information. Plate II is shown in Figure 101.

**The 1820s: Movement Toward Grand Illustration.** The graphic trends established prior to the 1820s included the early use of proxy images as illustrations, and the incorporation of layered information on graphics with the emergence of the early

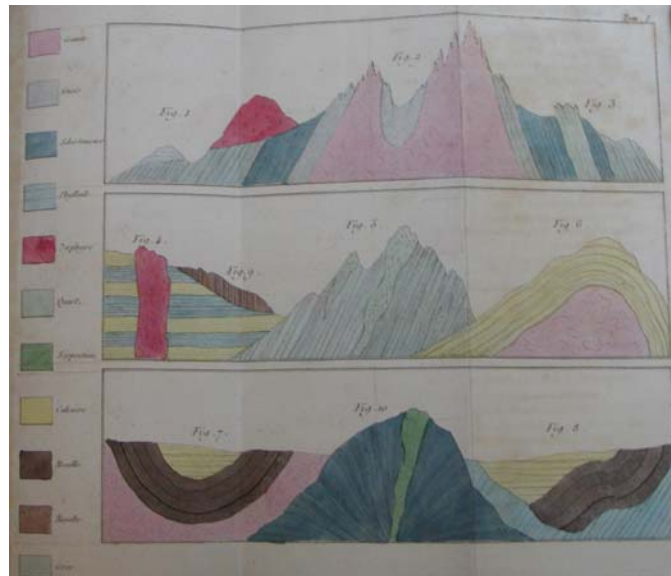


Figure 100: The same plate as Figure 99, reprinted in a later version. The colors are much lighter and easier to discern. (From Aubuisson de Voisins, 1828 – 1835)

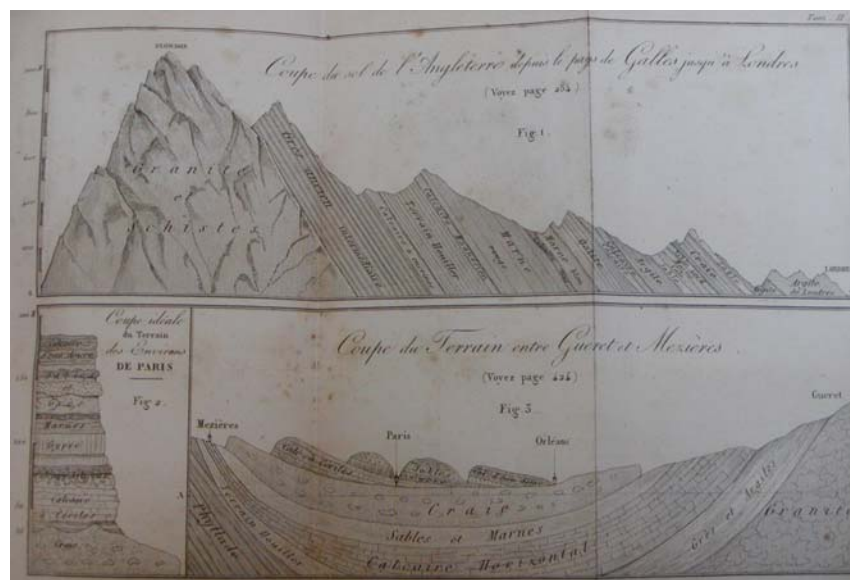


Figure 101: An early geological plate depicting inferred structure, and utilizing direct labels, as well as a numerical scale on the left side. (From Aubuisson de Voisins, 1819)

geological texts. There also did not appear to be a plethora of graphics within any text; this is probably due in a large part to the expense of the reproduction processes widely used during the period. In the 1820s, some of these trends continued, including the scarcity of images in some texts and a continued use of pictorial images as illustrations.

However, some texts broke from the older traditions, and included substantially more illustrations within each volume.

Maccullough's (1821) and Leblond's (1824) publications included no graphics. Eaton's (1824) text included only three illustrations, although a massive foldout in the beginning was a geological profile from the Atlantic Ocean to Lake Erie. The graphic was impressive with an included cross sectional view along the profile, direct labels of place names, and rock types listed directly on the cross section, with a scale at the bottom. The foldout also incorporated three proxy images above the cross section. A representation of Niagara Falls utilized alphabet labels, which were explained in annotation under the graphic. The last graphic was a foldout map with cross section. It was hand colored, although it did not have a color key. It also included direct labels, labeled rock lithologies, and a scale at the bottom of the illustration. Although graphic inclusion in the text was minimal, the information included on two of the graphics was layered and detailed.

Mawe's (1825) text was also sparsely illustrated with only four plates. The frontispiece was a proxy image, depicting a Brazilian miner washing through soil for gold and diamonds. "Illustration" does not appear to be the proper description for the frontispiece: This graphic is an inserted painting. As a proxy, it does not include any additional layered information, however. The last plate, although not nearly as elaborate, is similar: The lapidary equipment is strictly a pictorial representation. Proxy images likewise comprise the second included plate: The colored representations of the minerals, although proxies, show attention to detail. The third plate, also colored, is divided into three sections. This plate is reproduced in Figure 102. Alphabet labels are utilized on the graphic. The coloration in the plates is extremely vivid, and can be

characterized as garish and unnatural in hue. Furthermore, there is no color key for the colored sections.

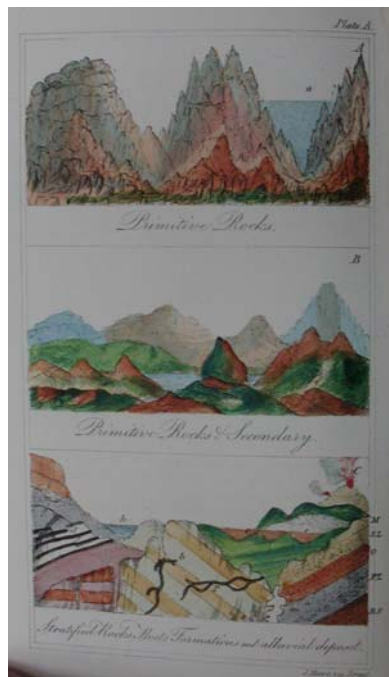


Figure 102: Colored sections; note the absence of a color key, although direct labels are used. (From Mawe, 1825).

There are other texts published between 1820 and 1830 that contain few insignificant illustrations. Scrope's (1827) publication contained an atlas as illustration; Devèze de Chabriol's (1827) text likewise included a map at the end. Girardin and Lecoq's (1826) book inserted three plates at the end: Simple line drawings of crystallographic shapes comprised Plate I, while equipment and natural rock specimens comprised Plates II and III, respectively. De la Beche's (1830b) *Geological Notes* was also sparsely illustrated with only two graphics.

Bakewell's (1829) edition added more graphics from the 1813 original; a total of six plates and two wood engravings are in the text. One wood engraving is a proxy image with no additional information, while the other has minimal alphabet labeling.



Figure 103 reproduces the labeled proxy. In addition to the low data density, the heavy and numerous lines constitute chartjunk; moiré lines result from shading.

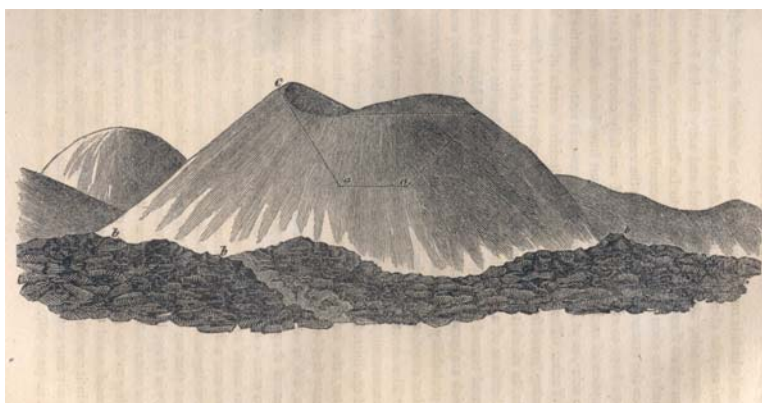


Figure 103: Wood engraving with limited labeling in Bakewell's revised text. Note the low data density, and the large amount of chartjunk. (From Bakewell, 1829)

Although many of the earlier established trends continued in geological texts between 1820 and 1830, there were new directions of growth as evidenced by some of the texts. Some publications followed Eaton's (1824) and Mawe's (1825) grand use of illustrations, and incorporated numerous plates or wood engravings when compared to earlier texts. Examples uncovered in this research investigation include books authored by Conybeare and Phillips (1822/1978), Cuvier and Brongniart (1822/1829), Mantell (1822), Buckland (1824), De la Beche (1824a, 1830e), Scrope (1825), and Ure (1829).

Conybeare and Phillips' (1822/1978) text incorporated three plates, and 23 wood engravings. This publication is one of the earliest uncovered that utilized a moderate number of wood engravings. Figure 6 reproduced one of the wood engravings; information is inferred in the section, and both direct and alphabet labels are included. Approximately 25% of the wood engravings did not incorporate extra information, however. The most common addition to the Conybeare and Phillips' graphics was alphabet and direct labeling.



Cuvier and Brongniart's (1822/1829) text did not incorporate wood engravings; instead, the illustrations were inserted within 18 plates, which were numbered as Plate 1a to Plate 11. There was also a foldout map. Of the 18 plates, nine plates included only proxy representations of fossils from the area. The seven plates that depicted sections showed mostly labeled information: The sections were natural exposures, and not inferred. Alphabet labels were the addition to the pictorial sectional views. The map was colored; it was the one graphic that represented inferred data.

Mantell's (1822) *The Fossils of the South Downs, or the Illustrations of the Fossils of Sussex* is grandly illustrated with 42 plates and seven wood engravings. Mary Mantell, wife of the author, engraved the illustrations after drawings by her husband. The wood engravings inserted within the text are diverse in their nature: Whereas some of the graphics are inferred, and incorporate alphabet and direct labels, other graphics are heavily shaded pictorial images with a large percentage of chartjunk. Figure 104 reproduces a semi-labeled proxy, with the annotations below the graphic. The alphabet

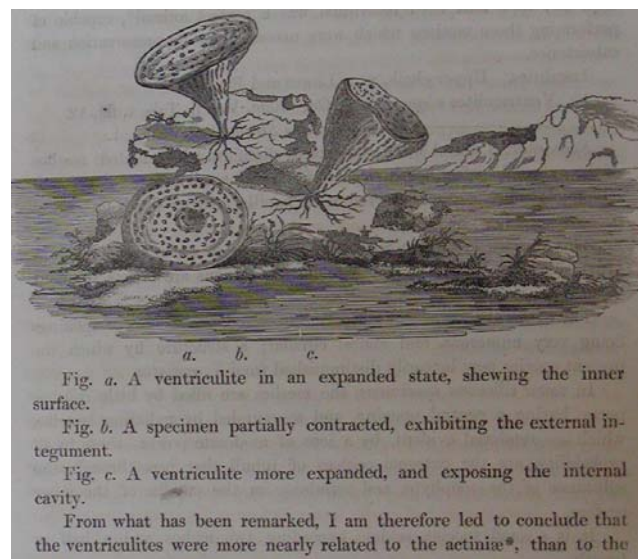


Figure 104: Inefficiently labeled proxy image, with annotations explaining the specimens. Note the heavy chartjunk. (From Mantell, 1822).

labels are not entirely clear as to which ventriculite they stipulate. However, other Mantell wood engravings are clean drawings with little chartjunk, and provide layered information within the illustration. Figure 105 presents the graphics from page 296, depicting a map view as well as a sectional view. The wood engravings utilize direct labels, as well as number labels for identification.

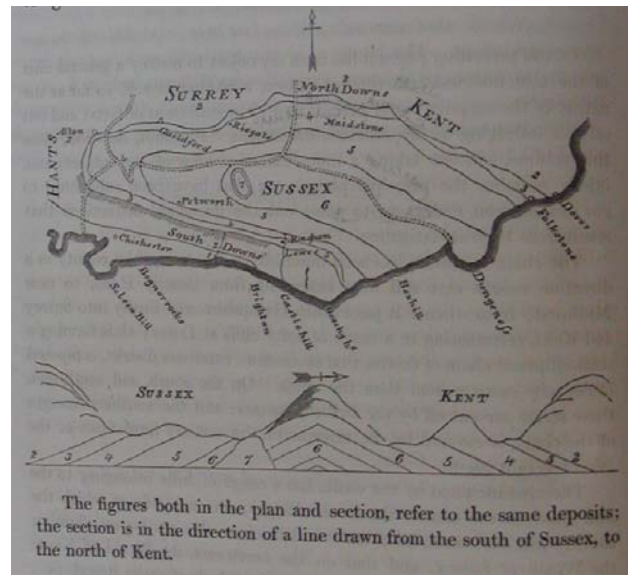


Figure 105: Map view and sectional view from Sussex to Kent. The graphic incorporates direct labels and numerical labels, and has very little chartjunk. (From Mantell, 1822)

Although some of the wood engravings are well done, the 1822 text can be characterized as elaborate through the plates. The plates incorporate color; the colors' representation is identified at times with color keys, and at other times with direct labeling on the graphic. Figure 106 reproduces a geological map of the southeastern part of Sussex. There is a color key at the bottom, as well as a geological section of the area. The color key for the geological map is important: Formation colors on geological maps had not yet been standardized. Although the colors are identified in a key at the bottom, they are not true Tuftian colors, or the tones found in nature.



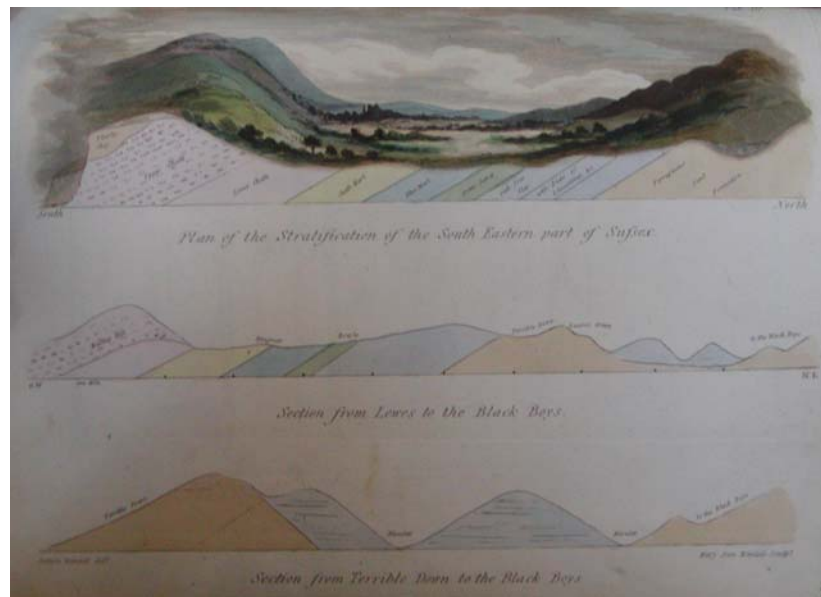


Figure 107: Three colored sections with inferred information and direct labels. The top section also presents topography. (From Mantell, 1822)

with colored maps. Figure 15 and Figure 37 reproduce two of the interesting illustrations from this text. The graphics utilized direct and alphabet labels. However, it is De la Beche's 1830 *Sections and Views* that is claimed as a very innovative text. Most of the 40 plates have layered information in the form of direct or alphabet labels; only six of the plates are purely pictorial in nature. Figure 17 presents a typical illustration. However, some of the De la Beche graphics were innovative: Figure 38 shows a later reprint of a persuasive graphic whose function was educational, and not illustrative. De la Beche was also apparently one of the earliest geological authors to present geological sections in a small multiple format; one of these small multiples is reproduced in Figure 39.

Scrope's (1825) study on volcanoes of France was well illustrated with three plates as well as wood engravings in the text. The wood engravings tend to be heavy with line shading, and also incorporate unnecessary chartjunk within the graphics. Some direct labels are utilized, as well as alphabet labels. Figure 108 shows one of the more interesting wood engravings: Scrope's Figure 2 ineffectively uses alphabet labels at the

bottom of the inferred section. The labels are not easy to detect since they blend in with the excessive shading of the graphic. However, this figure does incorporate arrows that point to the *direction* of force of rising magma. Directional information was not common in early geological illustrations.

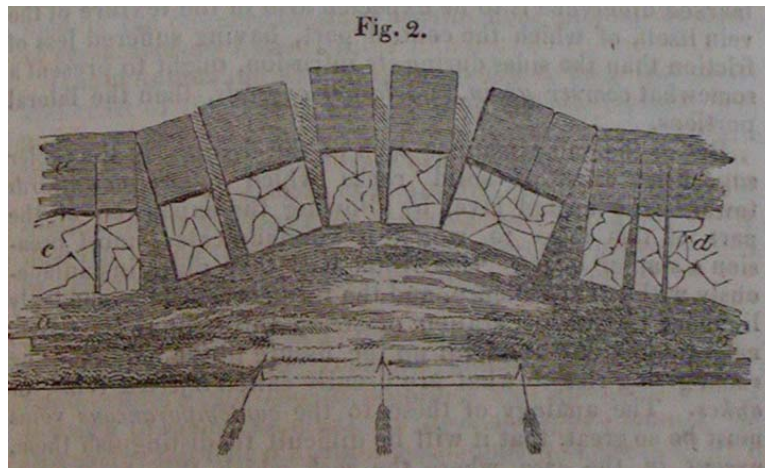


Figure 108: Early graphic showing directional information in the form of the arrows indicating direction of force. Note the poor use of alphabet labels that almost disappear in the excessive ink, or chartjunk. (From Scrope, 1825)

Of Scrope's (1825) three plates, two incorporate color. Plate I uses spot color on a global map, while Plate III presents three sectional views, two of which are colored. All the colored graphics do include color keys. Plate II, in grayscale, has six figures; all but one are pictorial landscape views. The graphics in Plate II are very rough, and have excessive chartjunk in the form of unnecessary ink. Figure 109 reproduces Plate I. This plate is unusual in that it is an early graphic attempt to correlate volcanic eruptions with mountain elevation. The link between volcanoes and mountain ranges (orogenic activity) would eventually become supporting evidence for plate tectonics 135 years later.

Ure's 1829 text was an elaborate volume; it was bound in embossed leather, with gold leaf embellishments. Included in the book are 7 plates and 51 wood engravings. However, most of the wood engravings are untitled and have no additional information





Figure 109: An early graphic attempt to associate volcanic activity with mountain ranges. Spot color is added to the map to represent volcanic eruptions, and elevation levels. The color key is included at the lower left. (From Scrope, 1825)

layered on the graphics. A total of three figures had alphabet or numeric labels, and one of the graphics had direct labeling of place names. The plates were also univariate in their data: Six of the seven plates in Ure's (1829) book are proxy depictions of fossils. Only the last plate deviates from the previous six, and presents a sectional view of a cavern in Franconia.

**The 1830s: A Change in Audience.** In the 1820s, the total number of graphics in texts noticeably increased. The initial appearance of early geology texts in 1813 was also the beginning of the inclusion of illustrations with layered and inferred information. These graphic types continued in the 1820s; graphic innovations from 1820 to 1830 included the use of wood engravings, the addition of directional information, and an elaborate use of color in some of the illustrations. The type of texts, as well as the embellishment of illustrations, indicates that these publications were intended for an elite class of readers. However, the audience of geology texts appears to change in the 1830s. An increased use of wood engravings made for efficient incorporation of illustrations in texts, and illustrations appear to have been a selling point for general science books. Not

only could the growing professional class afford texts, but the culture of the period also valued the natural sciences. This appears to be a favorable situation for the development of new, general geology texts. While books with elaborate colored illustrations became scarce, the highly illustrated general texts became popular.

Even with the increased use of wood engravings, the addition of illustrations was still a costly addition to a book. Several books published in the 1830s did not include graphics, including De Luc (1831), Omalius d'Halloy (1831), Finch (1833), Reboul (1833), and Moore (1834). Other publications were sparsely illustrated, such as Boubée (1833) with only one included graphic. The graphic, a colored section depicting the infilling of basins and igneous intrusions, includes more information than most geological illustrations of the time; labeled epochs and a color key are incorporated. It is shown in Figure 110.

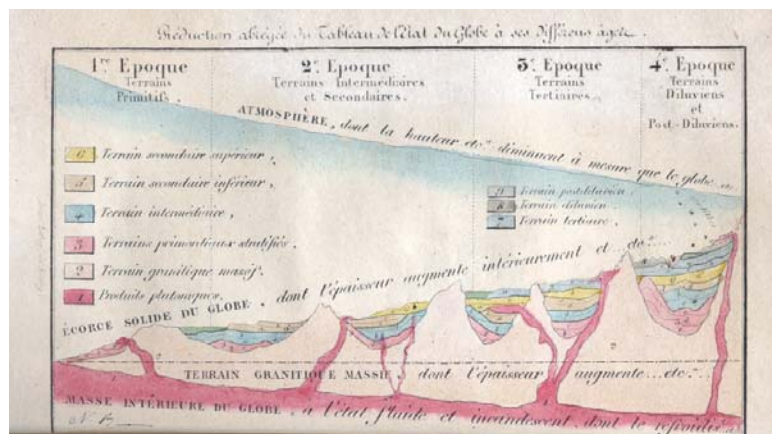


Figure 110: Frontispiece of graphic with inferred information. Color, direct labels, and alphabet labels are all present. (From Boubée, 1833)

Humboldt's (1832) text also included only two plates. However, as discussed in Chapter 1, the graphic representation of isotherms was quite unusual; most geology illustrations are pre-graphic, and do not depict data via identical-measurement lines. Humboldt's plate is reproduced in Figure 4.

Reboul's (1835) solitary graphic depicted three sections, with alphabet lettering added to the figures. John Phillips' (1835) text also utilized only two pages of graphics at the end of the text, portraying a map and sectional views. Although Mantell's (1836) small publication included only one illustration, the pictorial representation of a fossiliferous rock was a work of art, reminiscent of the grand illustrations of the 1820s. It appears that special metallic paint was used to create a unusual sheen within the graphic.

Most geology publications were industriously illustrated, however. Graphic inclusion appears to have been valued by Cuvier (1831), Lyell (1830-1833/1991; 1838), De la Beche (1831, 1833a, 1835, 1837e, 1839b), Mantell (1833, 1838), Omalius d'Halloy (1833), Boase (1834), Thomson (1836), J. Phillips (1837-1839), Lecoq (1838), Murchison (1839), Bakewell (1839), and Macgillivray (1840). The number of texts containing generalized geological information had also increased. Because the science of geology became very fashionable, the rising educated class created a lucrative market for elementary geology texts. Many geological authors were quickly publishing in this textbook market, trying to capture a share of the financial profits to be made (Rudwick, personal communication, July 3, 2002).

Cuvier's (1831) *A Discourse on the Revolutions of the Surface of the Globe, and the Changes Thereby Produced in the Animal Kingdom* incorporated 10 plates within the text. The subject of the illustrations reflected Cuvier's specialty areas: All figures reflected anatomy or paleontology, and were general proxy representations.

Lyell's (1830-1833/1991) *Principles of Geology* volumes are rather interesting in that they appear to be elementary texts on the surface. However, Lyell's texts actually appeal to dual audiences: an audience of specialists, and an audience of generalists (Rudwick, personal communication, July 3, 2002). Lyell's grand theorizing and



promotion of uniformitarianism was not without its critics, however. De la Beche, advocating the collection of facts as opposed to production of a grand model, criticized Lyell's theories through scientific caricatures. Rudwick (1998) noted that Lyell was running into serious problems by the late 1830s, since he had failed to convert geologists such as Scrope and De la Beche to his beliefs. The result was that *Principles of Geology* was reinvented, and published in a very different format. The 1838 *Elements of Geology* was aimed at the general public, and was much pared down from the original source.

Volume I of Lyell's *Principles of Geology* included 33 wood engravings, many with inferred information, direct labeling, and alphabet labeling. Whereas most of the illustrations were inferred information from nature, there were a few general diagrams whose purpose was educational; Figure 11 reproduces the sinuosity of rivers. The inferred graphics tend to have clean lines, and very little chartjunk. Figure 12 replicates the volcanic island of Santorin, with an inferred sectional view. However, Lyell still incorporated proxies and labeled proxies in his text that were heavily inked and data-poor; almost half (15) of the included figures were of this type. Figure 111 provides an example of a heavily inked labeled proxy.

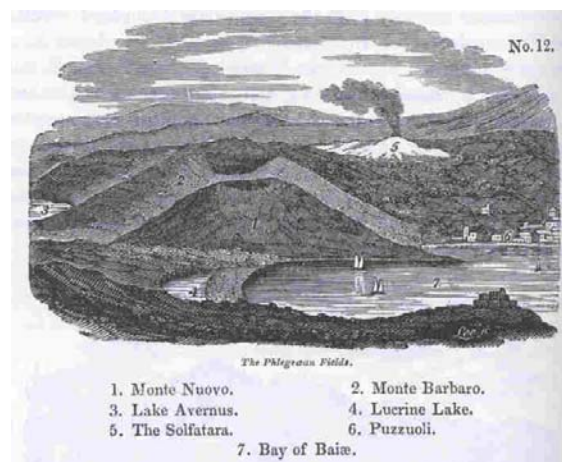


Figure 111: Labeled proxy landscape with heavy chartjunk and hard-to-read labels. (From Lyell, 1830/1991)

Lyell's second volume of *Principles of Geology* utilized very few illustrations. Most of the nine wood engravings were proxy views; only one minimal map and two very basic sectional views incorporated additional information on the illustrations. However, there was a return to more graphic inclusion with the third volume of *Principles of Geology*. Five plates and 93 wood engravings were inserted into the text. Similar to the first volume, many of the graphics are cleanly illustrated with inferred information. Figure 13 reproduces a labeled sectional view. Educational diagrams are included in this volume as well; Figure 14 is an illustration revealing the effects of vertical exaggeration. Fewer heavily inked proxy images, or labeled proxies, are included in the third volume: Eight proxies with excessive chartjunk are present, as well as two proxies with finer representation. Lyell also began to include more of the generic diagrams, as opposed to the inferred representations of natural landscapes. A total number of 13 general diagrams is included in the third volume of *Principles of Geology*.

When Lyell recast his theories into a general geology text in 1838, he continued to rely on inserted illustrations. The 1838 *Elements of Geology* was profusely illustrated with one colored plate, and 294 wood engravings. The wood engravings are similar to those incorporated in *Principles of Geology*; there are simply many more of them included in this text. The colored frontispiece is classic: It depicts a stylized example of the rock cycle, and is shown in Figure 112. Colors are used effectively to show the different types of rocks; volcanic and plutonic igneous rocks cut across country rock in tones of pink and lavender. Metamorphosed areas are represented in blue, and are colored across the existing strata lines. Finally, the forming sedimentary rocks are highlighted in yellow. Lyell also included alphabet labels in this inferred diagram.

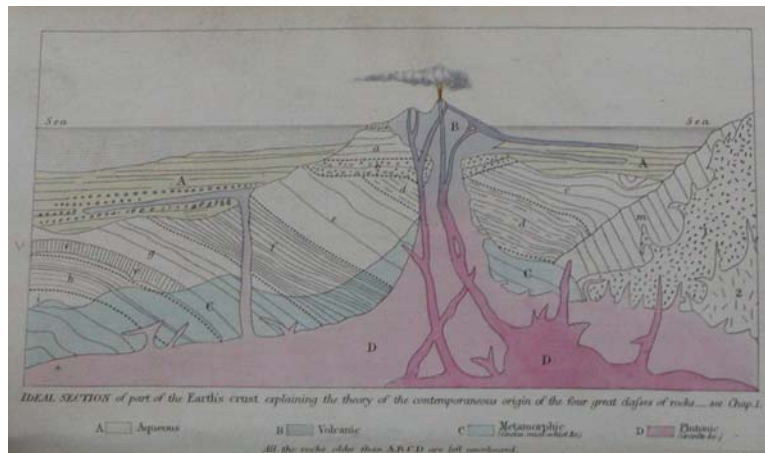


Figure 112: An early illustration of the classic rock cycle, with added color, color key, and alphabet labeling. (From Lyell, 1838)

De la Beche published numerous texts in the 1830s, including *A Geological Manual* (1831), its revised and expanded third edition (1833a), *Researches in Theoretical Geology* (1834b), *How to Observe Geology* (1835), and *Report on the Geology of Cornwall, Devon, and West Somerset* (1839b). These texts have all been discussed in depth in Chapter 5. However, the illustrative publication trends, as well as De la Beche's graphic innovations, will be briefly summarized here.

*A Geological Manual* was a very successful text for De la Beche. Although Lyell published the first volume of *Principles of Geology* the previous year, De la Beche surpassed Lyell's graphic density with many more included illustrations. De la Beche incorporated 104 wood engravings in the first edition of *A Geological Manual*, a number that adds 59 more illustrations than the *combined* first and second volumes of Lyell's *Principles of Geology*. It appears that De la Beche was a far more visual person than his colleague. Many of the De la Beche graphics were pictorial views; Figure 40 and Figure 41 reproduce two of these proxies. However, De la Beche did utilize alphabet labeling in some of the illustrations. The expanded 1833 version of *A Geological Manual* also

included a graphic first: De la Beche inserted the first small format scenes of deep time ever published. Two of these illustrations are presented in Figure 19 and Figure 42.

The 1834 *Researches in Theoretical Geology* seemed to abandon its predecessors' illustrative edge. The text included only 46 wood engravings. However, some of the graphics appear to be an attempt to correlate variables without the use of numbers: Figure 21 shows the variances in pressure and temperature from a coastline. Small multiples are again utilized in this text; Figure 43 reproduces geological sections presented in a small multiple format. Perhaps the most unusual graphic inclusion in this text was De la Beche's frontispiece: He drew an inferred view of earth as seen from space. This illustration is reproduced in Figure 44.

De la Beche regained his visual edge with the 1835 *How to Observe Geology*. With 138 wood engravings, it was a very visual text. Alphabet labels were utilized, and new directional information was added to some of the graphics; Figure 45 shows the direction of earthquake waves. De la Beche also began to use visual metaphors for illustrating geological principles. Strike and dip is shown via books in Figure 20.

The 1839 *Report on the Geology of Cornwall, Devon, and West Somerset* continued the use of diagrams to facilitate viewer education. Figure 46 eliminates extraneous information, and cleanly illustrates a generalization De la Beche wished to convey to the reader.

Gideon Mantell, a surgeon, also attempted to write elementary geologic texts for supplemental income. Both *The Geology of the South-east of England* (1833) and *The Wonders of Geology* (1838) included numerous graphics. The 1833 text incorporated five plates of fossils and 65 wood engravings. Fossil proxies also comprised a large

portion of the wood engravings as well. However, there were 11 wood engravings that did have additional information added, either in the form of direct or alphabet labels.

Mantell's (1838) *The Wonders of Geology* is also well illustrated with five plates and 80 wood engravings. The wood engravings tend to be heavily inked, and add unnecessary chartjunk. However, the colored plates are multivariate, and detailed in their information. Plate III is a sectional view, with direct labels and good detail. It is reproduced in Figure 113. Although it does not have a color key, the rock types are directly identified. There is excessive chartjunk in terms of the heavy use of lines, but the layered information on the illustration does offer some compensation.

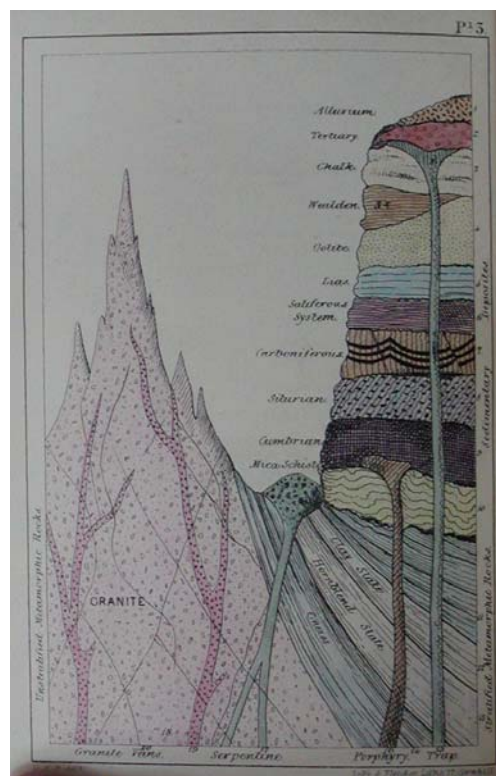


Figure 113: Colored sectional view with direct labeling of lithologies. (From Mantell, 1838)

Plate V portrays geological sections. The graphics are colored, with the lithologies either directly identified, or with numerical labeling and keys. This plate is reproduced in Figure 114. Within the plate, topography, rock types, geological age of

rock strata, and direction of bedding are all depicted. The graphic has the further advantage of incorporating a lot of information in a relatively small space: Tufte (2001) advocated shrinking graphics, in order to take advantage of the resolution capabilities of the human eye.

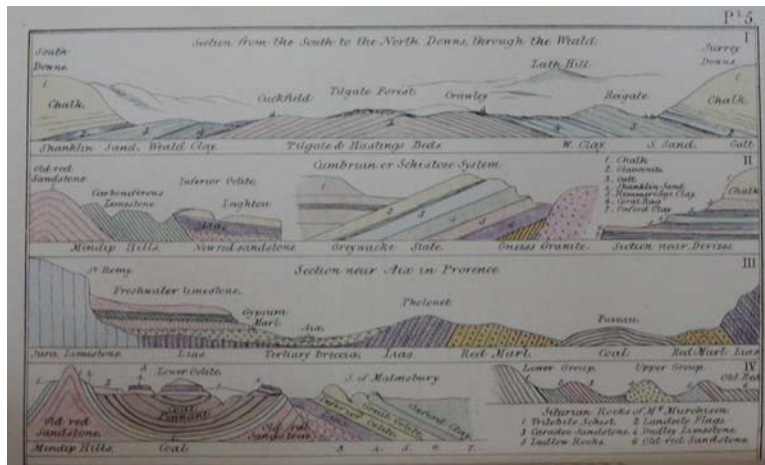


Figure 114: Sectional views, incorporating a lot of information in a relatively small format. This graphic takes advantage of Tufte's (2001) shrinking principle. (From Mantell, 1838)

A liberal use of graphics within in a text did not guarantee an effective use of graphics. Omalius d'Hallo's (1833) text included an accompanying atlas with 17 plates. However, the illustrations were typical mineralogical depictions, and were not exceptional. Likewise, Boase's (1834) text incorporated 24 wood engravings, but the graphics were more primitive than many contemporary wood engravings. The hachure marks and stippling used to distinguish formations have the same line width as the lines separating the formations. This is confusing to the viewer, and offers very little graphic data, with an overabundance of chartjunk.

Thomson's (1836) second volume also did not utilize graphics effectively. Whereas the first volume incorporated many crystallographic shapes, the second volume included only six graphics, with four of them being proxy views of glassware. The two

geological graphics were unexceptional, but did include alphabet labeling. The graphics of John Phillips (1837-1839) were also typical of the period. The 96 wood engravings of labeled proxies or inferred representations tend to be drawn cleanly, with little chartjunk. Additional information was added in the form of alphabet and direct labels. The proxy images that were included, however, did include a substantial amount of chartjunk in the form of excessive ink.

Lecoq's (1838) text included seven foldout plates representing fossils, landscape, and structure. The majority of the figures in the plates depicted volcanoes; additional information added to the graphics occurred as direct or alphabet labeling. Although the graphics were typical of the period, the frontispiece of the first volume provided the exception: Lecoq included a scene from deep time, with some of the animals partly submerged in the water. Although De la Beche had drawn the first true scene from deep time in *Duria antiquior*, he had not included any grand scenes from deep time in his texts. Instead, small vignettes were inserted in his third edition and French translation of *A Geological Manual*. Even if De la Beche had qualms about using an ancient scene in a text format, Lecoq obviously had no such reservations. He did not, however, incorporate the unique aquarium view used by De la Beche in *Duria antiquior*. Lecoq's frontispiece is shown in Figure 115.

Murchison's (1839) *The Silurian System* was not a general geology text; however, it was an important text of the age of focus, and its methodology did have applications for other geological situations. The two volumes were not targeted to a general audience. This was an expensive text, and was more specialized and scientific than many of the general geological interest books that were published in the 1830s. Murchison included 56 pages of plates, and 112 wood engravings within the text. The numbering of the wood



Figure 115: A frontispiece depicting a scene from deep time. Lecoq did not use the aquarium viewpoint that De la Beche did in *Duria antiquior*, but instead portrayed the animals partly submerged, or upon the beach. (From Lecoq, 1838)

engravings was confusing: A simple number in the upper right corner was the identifying factor. Most of the engravings did have added information, including alphabet labels, compass directions, and direct labels. Proxy images of fossils were present as well. Color was employed in some of the plates; very few color keys were utilized, however. This led to problems of interpretation for the viewer in some of the plates. The colors chosen were not always ones found in nature; in one section, a garish pink was an obnoxious choice.

Bakewell was still revising his geological texts in the 1830s. An 1839 edition examined included a total of eight plates, and 32 wood engravings. Although this number is increased substantially from the very first 1813 edition, the text was not as lavishly illustrated as a later Lyell (1838) or a De la Beche (1835) book. Some wood engravings did incorporate added information in the form of number and alphabet labeling. However, proxy images of fossils were included as well. The eight plates reproduced the six plates from the 1829 edition, with the exception that color was not



utilized in any of the figures. The two new plates were pictorial representations of fossils, including three figures of a gigantic trilobite.

The latest published geology text examined in this research study was Macgillivray's 1840 text, which incorporated 43 wood engravings. The font size of the text was extremely small, and engravings were often inserted within wrap-around text. The information added to the graphics was in the form of alphabet or direct labels. Although the illustrations are not exceptional, they are cleanly drawn, and exhibit little chartjunk. Figure 116 reproduces one of Macgillivray's figures.

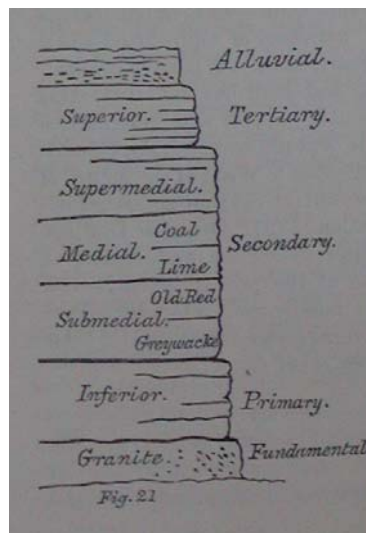


Figure 116: Wood engraving with direct labeling. (From Macgillivray, 1840)

**Absence of Mathematical or Relational Graphics.** Tilling (1975) noted that the fundamental mathematical tools were in place at the beginning of the 18th century for the construction and interpretation of simple graphs. However, she noted the absence of experimental graphs in scientific literature in the 19th century; even a century later, the examples of true mathematical graphs were sporadic at best. This observation was echoed in Beniger and Robyn's (1978) discussion of statistical quantitative graphics: Although throughout history numbers have existed alongside imagery, as in the case of maps,

representation via different graphical tools occurred in leaps as opposed to a steady progression. Graphical analysis of data reportedly emerged in regular scientific publications from 1830 to 1835, and the quantitative graphic only became an accepted part of statistics in the mid-1800s (Beniger & Robyn, 1978). Tilling (1975) further commented on the non-application of the mathematical graphic form. Even if graphics were present, they seldom were used for analyzing or commenting on the relationships they depicted. This observation has definitely been verified in this research study for geological graphics during the Golden Age of Geology. Howarth (1998) investigated the publications containing relevant graphs in mineralogy and petrology from 1800 to 1935; although some sparse usage was noted before 1840, rapid growth in graphic visualization occurred in the late 1800s. Very few true relational graphics were noted in this research study. Although the knowledge and tools existed for geologists to represent data mathematically, only in a few cases – for example, Humboldt’s (1832) isotherm – were data represented causally.

### **The Visual Nature of Geologists**

The inclusion of graphics within geology texts shows apparent progression from a few pictorial representations to more numerous labeled proxies, inferred representations, and general diagrams. This trend was no doubt influenced by the innovations in graphic reproduction during the Age of Geology, as well as an increasing cultural fixation on the natural sciences. However, a question remains as to the visual nature of geologists: Did the geologists in the early modern science value pictorial representation? Rudwick (1985) noted that visual communication in geology was of crucial importance, as evidenced by the display of large-scale diagrams and specimens at geological meetings. Also providing evidence for the visual nature of the early geologists are the artistic

endeavors recorded within their personal communication. Whereas printing techniques and the market for the final product influenced illustrations within texts, personal letters and caricatures were not mass-produced and distributed; these did not have similar pressures. The visual nature of the early geologists is reflected in such documents.

**Sketches in Letters.** Research conducted at the National Museum of Wales in Cardiff revealed that geologists often illustrated their letters. William Buckland (1816) included a beautiful sketch of fossil trees in a letter. William Conybeare was also visual in his correspondence: An 1821 letter contained six sketches of ichthyosaurus specimens; alphabet and direct labels were added, as well as annotations (Conybeare, 1821a). Another 1821 letter to De la Beche contained five sketches of the jaw of a crocodile (Conybeare, 1821b). Conybeare's (1824) letter included a very basic plesiosaurus sketch at the top of the letter, as well as sketches of plesiosaurus bones and the paddle limb.

Fossils were not the only illustration type found in correspondence between geologists; sketches of sections were also sometimes included. In his letters to William Conybeare, De la Beche included sketches of sections depicting the geology of Jamaica (De la Beche 1824b, 1824c, 1824d). The sections included direct labels, compass directions, and one was even colored with a color key for identification. The colored Jamaican section is reproduced in Figure 66. Adam Sedgwick (1830) included a precise sectional view in his letter to De la Beche. He added direct and number labels, with the numbers identified in a key below the graphic. Compass directions were also added; Sedgwick seemed concerned about the accuracy of his sketch, and noted the changes that were to be made. Foreign geologist Elie de Beaumont also included illustrations in his letters; an 1832 letter to De la Beche incorporates a very basic sketch with direct labels.

Finally, John Phillips (1840) drew a sketch depicting the position of the Lias, with direct labels, in a letter to De la Beche.

**Caricatures.** Caricatures drawn by De la Beche are discussed in Chapter 5. During this research study, only isolated examples of scientific caricatures drawn or commissioned by other geologists were discovered. De la Beche utilized scientific caricatures to comment on the activities of his colleagues, and to try to persuade them to accept his own views. Although several De la Beche caricatures were distributed, many De la Beche diaries and field notebooks contain caricatures that were not widely seen. It appears, therefore, that De la Beche's caricatures were a manifestation of his visual nature and cognition.

### **Quantitative Analysis of Graphics in Early Geological Texts**

The modified list of early geology texts that were investigated in this research study is presented in Appendix M. Although qualitative analysis of the illustrations revealed apparent trends in the number of included illustrations for the publication years, a quantitative analysis was conducted to verify or disprove this observation.

Graphic density was calculated for the texts; the data are listed in Appendix N. The total combined number of plates and wood engravings is divided by the total number of pages to reveal a text's graphic density. This method is slightly different from the calculation of graphic density for De la Beche's texts: Whereas the graphic density for De la Beche texts took into consideration the total number of *figures*, the graphic density for all geology texts examined in the age of focus is determined strictly by summation of total plates and wood engravings. The reasons behind this are threefold: Often the conditions of microcards did not allow an accurate determination of individual figures within plates; the cost of adding plates to texts was substantial, but not affected by the

number of drawings within a plate; and De la Beche, as the author and illustrator of his texts, did have a vested interest in the total number of figures he drew and included within a plate. Other geological authors were not similarly affected. The graphic density of geology texts published in the Golden Age of Geology is plotted against the year of publication in Figure 117.

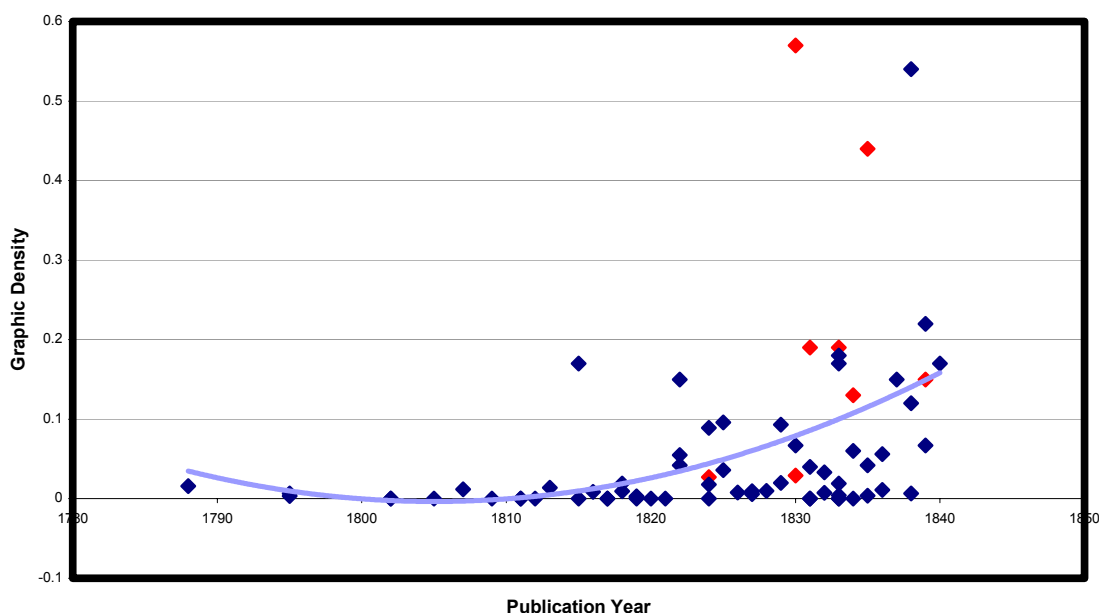


Figure 117: The graphic density of geology texts published from 1788 through 1840 plotted against publication year. Red diamonds indicate De la Beche texts. The polynomial trend line is in lavender.

The number of included illustrations (total sum of plates and wood engravings), as opposed to the graphic density, was also plotted against publication year, eliminating the total number of text pages as an affecting variable. Similar trends were revealed. This scatterplot is shown in Figure 118.

Measures of central tendency for publication year, graphic density, and total number of included illustrations were calculated using WebStat statistical software (<http://www.webstatsoftware.com/>). The summary statistics are presented in Appendix N, along with box plots of the data.

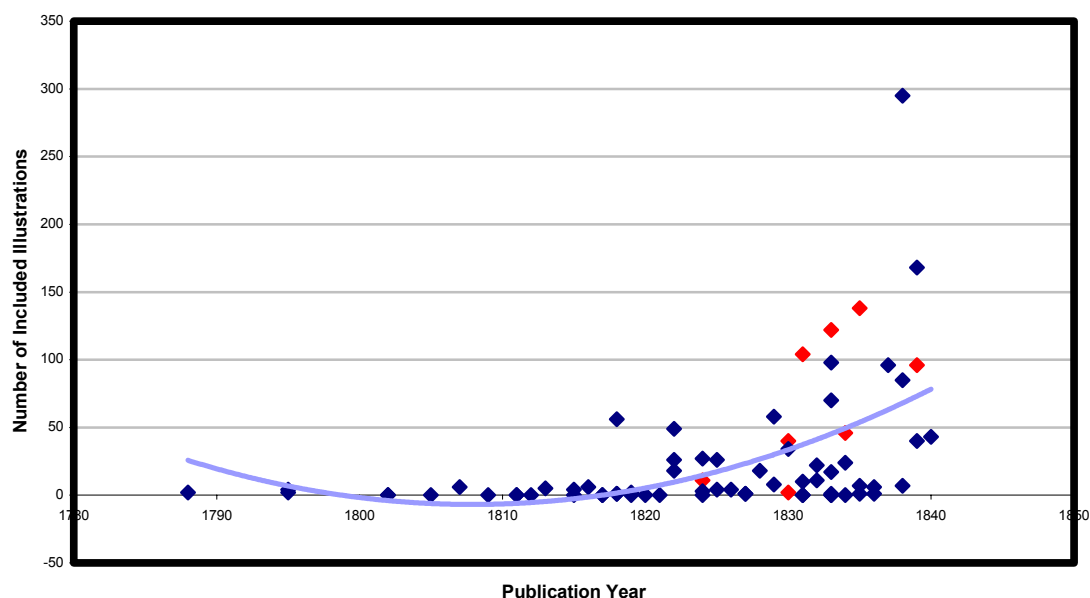


Figure 118: The total number of included graphics (summation of plates and wood engravings) of geology texts published from 1788 through 1840 plotted against publication year. Red diamonds indicate De la Beche texts. The polynomial trend line is in lavender.

The mode of publication years is 1833, while the median year for publication – 1827 – is weighted substantially toward the end of the period of focus; this supports the observation that the number of published general geology texts increased in the latter years, paralleling the increased use of wood engravings in texts, the growth of a professional class, and the cultural focus on natural history. The box plot for publication years, as shown in Appendix N, indicates that the majority of the texts examined were also in the latter period of the Golden Age of Geology. However, it should be remembered that selection of geological texts proceeded via several sampling approaches, which may have entered some bias into the sampling process.

The range for graphic density was computed from 0.00 to 0.57; interestingly, the high value represents the graphic density for De la Beche's (1830e) *Sections and Views*. Still, the addition of illustrations was expensive. This may explain the fact that the mode

for the graphic density was also 0.0. The median for graphic density was 0.014, a relatively low number. However, the mean of 0.065 indicated that some heavily illustrated texts raised the average graphic density. The box plot for graphic density, shown in Appendix N, also indicated few illustrations and low graphic density for the majority of texts.

The range for the total number of illustrations was also diverse, from the minimum of 0.0 to the maximum of 295. The mode for total illustrations was again 0.0, while the median was also a low 4.5. However, the heavily illustrated texts examined did raise the average number of illustrations to 26.78. The box plot for the total included illustrations, presented in Appendix N, is heavily skewed toward a low number of included graphics. Several high outlier values have been boxed in the graphic.

Hypothesis testing was also done with the correlation coefficients for both publication year and graphic density, and publication year and total number of illustrations. The detailed statistics are included in Appendix N. The assumptions for the hypothesis testing are a randomly selected sample, normal population distributions, and homoscedasticity. Initially, the sampling of geology texts published between 1788 and 1840 was convenient and purposive in the pilot study; texts were initially limited to those books that were held in Louisiana State University's Middleton and Hill Memorial (Rare Book and McIlhenny collections) libraries, as well as those texts that could be obtained on interlibrary loan, or that were reproduced on microfiche or microcards. As the study progressed, more and more texts were identified from text citations, history of geology texts, history of geology facsimile text series, and interviews with historians of geology. Sequential sampling proceeded until saturation was achieved. Elimination of paleontology and mineralogy texts did enter some bias into the sampling, however. The

elimination of text translations, as well as most secondary editions, possibly added further bias to the study. Nonetheless, the sample should be considered representative, since the method of obtaining data did not involve any overt attempt to introduce bias for graphic inclusion; the elimination or selection of texts was made with respect to the type of geology text or the originality of the text (as opposed to secondary publication), and was not made on the basis of illustration content. A true random sampling would not have yielded the amount of data collected in this study.

When hypothesis testing was conducted for the publication year and graphic density, the  $t_{ts}$  value calculated was 3.31. This was sufficient to reject the null hypothesis, and accept the alternative hypothesis that a relationship exists between the publication year and the graphic density. The decision to reject the null hypothesis is made at the 99% confidence level.

Similar results were achieved with hypothesis testing for the correlation coefficient between the publication year and the total number of included illustrations. The  $t_{ts}$  value calculated is 3.88. The null hypothesis is rejected, and the alternative hypothesis that states that there is a relationship between the publication year and the number of included illustrations is accepted. The decision to reject the null hypothesis is also made at the 99% confidence level.

## Discussion

Qualitative analysis of geology texts published in the Golden Age of Geology, using Tufte's (1990, 1997, 2001) theory of graphic design, revealed four general stages of illustration trends. Proxies or pictorial images, heavy with chartjunk and low in data density, were the first graphics included in publications. The arrival of general geology texts – in this study, Bakewell's (1813) book – marked the arrival of labeled proxy



images, as well as inferred structural representation. The inclusion of graphics evolved, and the 1820s were marked by several texts with very elaborate illustrations; color was lavishly incorporated, and graphics were detailed. Often the graphic representations appeared to be works of art as opposed to data illustration. The 1830s marked the fourth stage of graphics in this study: The increased use of the cheaper illustrative reproductive method of wood engraving, plus a demand for general texts from a growing professional class, resulted in texts with more prolific use of illustrations. However, the grand use of color – an expensive addition to illustrations – disappeared as the audience of the texts changed from a specialized, elite group of geologists to a general, educated audience.

The graphic types identified in this study – proxies, labeled proxies, inferred representation, mathematical or causal graphics, and small multiples – were plotted to show the range of usage in geology texts. Figure 119 is the result. Proxy images were the first graphic vehicle, and tended to be utilized as illustrations throughout the period of

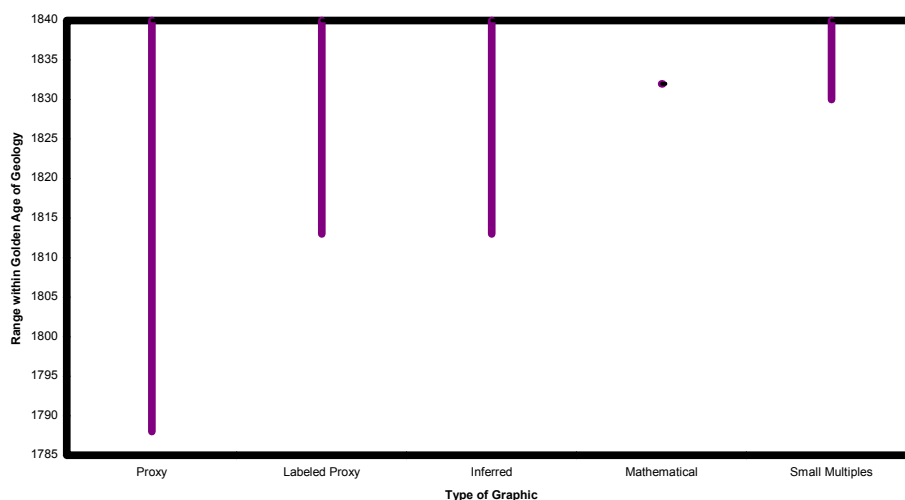


Figure 119: The ranges of the different types of graphics (proxies, labeled proxies, inferred graphics, mathematical graphics, and small multiples) as discovered in this research study. The period of focus is 1788-1840. Note the failure for causal or mathematical graphics to materialize as a preferred vehicle of representation.

focus. Most proxy images were heavily inked, resulting in high chartjunk and low data density. However, proxy images were eventually supplemented with labeled and inferred graphics. De la Beche (1830e) had the first use of a small multiple, and no other geologist applied this graphic form in the same way. However, De la Beche continued to graphically represent sectional views in this format. Mathematical graphics, depicting causal relationships, were not as prevalent. Only Humboldt's (1832) text revealed a true mathematical graphic in this research study. Geology appears to have remained in a pre-graph era at the end of the Golden Age of Geology.

Other trends and modifications to graphics in geology texts were noted in this research investigation. Types of modifications to graphics, such as alphabet labeling, direct labeling, use of scales, and directionality, were observed over the age of focus. The density of data and the incorporation of chartjunk were likewise recorded. Depiction of illustration evolution, as revealed through Tufteian analysis, required a modification of current graphic forms in order to adequately present the data and make the trends more visible. This resulted in the creation of a new graphic form: The coded small multiple supplies the illustration in the lower right corner, while colored sections surrounding the illustration quickly inform the viewer of the graphic modifications. Figure 120 presents a coded small multiple showing the evolution of geology graphics throughout the Golden Age of Geology.

Geological illustrations changed and developed from 1788 to 1840, but geological graphics had not yet matured by the end of the Golden Age of Geology. The wide acceptance and inclusion of causal or mathematical graphics would occur after 1840. Other changes in illustrative technique occurring after the Golden Age of Geology would also eventually benefit graphic form. For example, proxy images in the age of focus

Figure 120: Coded small multiple showing the evolution and modifications of graphics during the Golden Age of Geology.

were very heavy in chartjunk, and low in data density. Of course, most proxy images

today are supplied with photographs, which can provide infinite data in a single

were not as fortunate. The acceptable illustration used heavy shading, and exhibited too much non-data ink by Tuftean standards.

Although information did become layered, leading to the multivariate nature of graphics in the Golden Age of Geology, the imprecision of the wood engraving as a method of illustration reproduction probably affected the *amount* of information that could be layered within a small drawing. However, as graphics evolved to represent inferred information, and later, general educational information in a diagrammatic form, their usefulness as visual tools for science learning increased. The importance of visualization for education cannot be underestimated: Latour (1990), when noting the significance of the evolution of perspective, stated that the “rationalization that took place during the so-called ‘scientific revolution’ is not of the mind, of the eye, of philosophy, but of *sight*” (p. 27). With effective illustrations, the author can present absent scenes or objects that allow the viewer to perceive the original object or data without significantly altering the form. Perhaps Latour (1990) most effectively summed this up with his statement, “If you want to understand what draws *things* together, then look at what *draws* things *together*” (p. 60). The first toddling steps toward a visual culture of geology were taken during the age of focus.

## Chapter 7: Results and Discussion

### The Role of Henry T. De la Beche and His Geology Graphics – Golden Age of Geology and Today

Throughout this investigation, the main research focus has been the determination of the role of Henry T. De la Beche and his geology graphics in early modern geology, and their implications for geology education today. Three subquestions were identified to effectively channel the direction of study. The historical context in which modern geology emerged is examined in Chapter 4; the graphic innovations and contributions of Henry T. De la Beche to geology and geological education are discussed in Chapter 5. Chapter 6 investigates the nature and progression of geological graphics in the period of focus, as revealed through Edward R. Tufte's theory of graphic design. The data and discussions from these subquestions, as well as additional data relating to De la Beche's educational endeavors, will now be combined to reveal Henry T. De la Beche's role in early modern geology. However, Henry T. De la Beche's influence should not end with the Golden Age of Geology: Inferences can be made for the integration of De la Beche's graphic innovations within the curriculum, as well as the incorporation of the history of geology in the geoscience classroom.

#### Educational Endeavors of Henry T. De la Beche

Henry T. De la Beche's publications influenced the geological thought of elite scientists, professional geologists, and the general population. Some texts, such as *Annales des Mines* (1824) and *Sections and Views* (1830), were written and illustrated specifically for an audience of De la Beche's contemporaries in the elite geological circles of England. Conversely, general geological texts, such as *A Geological Manual* (1831) and *How to Observe Geology* (1835), were attempts to bring geological

understanding and awareness to a growing population of educated professionals. De la Beche educated many different types of readers through his texts and illustrations. However, the publications of Henry T. De la Beche are not the only surviving evidence of his educative nature: De la Beche also advocated education in ways other than his published illustrations and texts. As the first government geologist, Henry T. De la Beche was in a unique position to alter the government's – indeed, the entire public's – perception of geology; he was also able to direct the influence of the young science. De la Beche's educational mindset is evidenced by his activities in the British Geological Survey, and the establishment and functions of the Museum of Practical Geology, the Royal School of Mines, and the Mining Record Office. De la Beche believed that science should be of service to society, and the facts collected by scientific endeavors should be used to educate those employed in fields affected by the science, as well as for general benefit of the population. Even though his proposals sometimes brought him into direct conflict with England's highly ingrained social class system, De la Beche did not waver from his original goals. Some contemporaries considered him a class traitor because he supported education for people outside the elite social circles.

### **Geological Survey of Great Britain**

In 1835, the Ordnance Geological Survey was founded, and Henry T. De la Beche became the first government-employed professional geologist in England. Not only was De la Beche the first director of the survey, but he was also its sole scientific officer for many years (Dunham, 1991). Therefore, the success or failure of the new government-sponsored geological endeavor largely depended upon De la Beche's personal efforts and skill. De la Beche obviously performed well within this new institution: The maps and

sections were equal or superior to those produced by other countries, and the rapidity at which they were produced was exceptional (Flett, 1937).

Although De la Beche had once been the leisurely gentleman-geologist, he appeared to have no great difficulties in transitioning to a working professional. In fact, his loyalties seemed to shift rather quickly to his new position. Knell (2000) discussed one incident in which De la Beche requested the services of an old friend, William Sanders, to help in the survey work near Bristol. Although Sanders enjoyed the work and anticipated a similar task the following year, De la Beche severed the relationship; Sanders' expenses had been excessive, and De la Beche elevated the efficiencies of his organization above any previous loyalties he might have once had toward an elite geological contemporary.

Undoubtedly, De la Beche's unwavering loyalty to the Ordnance Geological Survey, the superior maps created, and the brisk production all combined to ensure a successful organization. As the Geological Survey grew, however, it would be difficult for De la Beche to personally inspect all products generated under his leadership. He sought consistency in the mapping process, as well as in the products created, by issuing explicit instructions to the local directors of the surveys of Great Britain. The letter dispatched on May 22, 1845 has been archived in the British Geological Survey; its stated purpose is to present a "general mode of observing and recording facts, during the progress of the Geological Survey, by which systematic investigations and uniformity of results may be secured" (De la Beche, 1845a).

The letter detailed De la Beche's method for rigorous observation in the field; precise instructions and special considerations are given for fact collection of igneous rocks, sedimentary deposits, metamorphism, and structural features. However, De la

Beche did not only include within his letter a recipe for consistent geological map success: Henry T. De la Beche did not miss the opportunity to educate the local directors as to what they were doing, and why. Included in the letter are many examples of the importance of the survey work to other areas of study. De la Beche (1845a) noted the parallel of the Geological Survey with the mining industry, and proposed that eventually the information of geologists and engineers would be united: “A body of men may be formed . . . constituting one of great value to the country.” De la Beche also informed the directors as to the influence of geology on agriculture, and urged them to take advantage of the practical information to be gleaned from the farmers. The importance of geological knowledge in the selection of road materials and building stones was discussed; geological influences in engineering considerations were likewise mentioned. De la Beche did not fail to discuss the handling of specimens gathered during survey work, and suggested the manner in which these should be labeled to provide clear and necessary information for the future. De la Beche (1845a), mindful of the general population that the Geological Survey ultimately served, acknowledged that science should serve the people; he tried to ensure that “the public may obtain those results which it has a right to expect from this branch of public service.”

Therefore, Henry T. De la Beche educated his directors. He informed them as to the proper procedures to be followed when surveying the countryside, the reasons the survey was performed, and its importance beyond geological considerations. De la Beche’s instruction and method of operation did not end with the directors receiving this letter, however. Fuller (2001) discussed Henry Darwin Rogers, an American geologist who became the first American admitted to the Geological Society of London. One of the four signatures on his proposal paper was none other than Henry T. De la Beche’s.



While awaiting the decision of the Geological Society, Roger joined De la Beche in Devon, and was educated by De la Beche as to his procedures for geological surveying and fieldwork. When Rogers returned to the United States and surveyed Pennsylvania, he brought the influence of Henry T. De la Beche across the Atlantic Ocean.

Many other geologists who learned survey work under Henry T. De la Beche dispersed around the world, and carried his influence to other countries. Thomas Oldham became the Local Director of Ireland in 1844, and later founded the Geological Survey of India. Andrew Ramsay was named the Local Director of England and Wales. William Logan eventually founded the Geological Survey of Canada, while Alfred Selwyn was at one time the director of the geological survey in New South Wales, and later the director in Canada. Figure 121 presents a concept map illustrating some of the far-reaching influence of Henry T. De la Beche on geological survey practices.

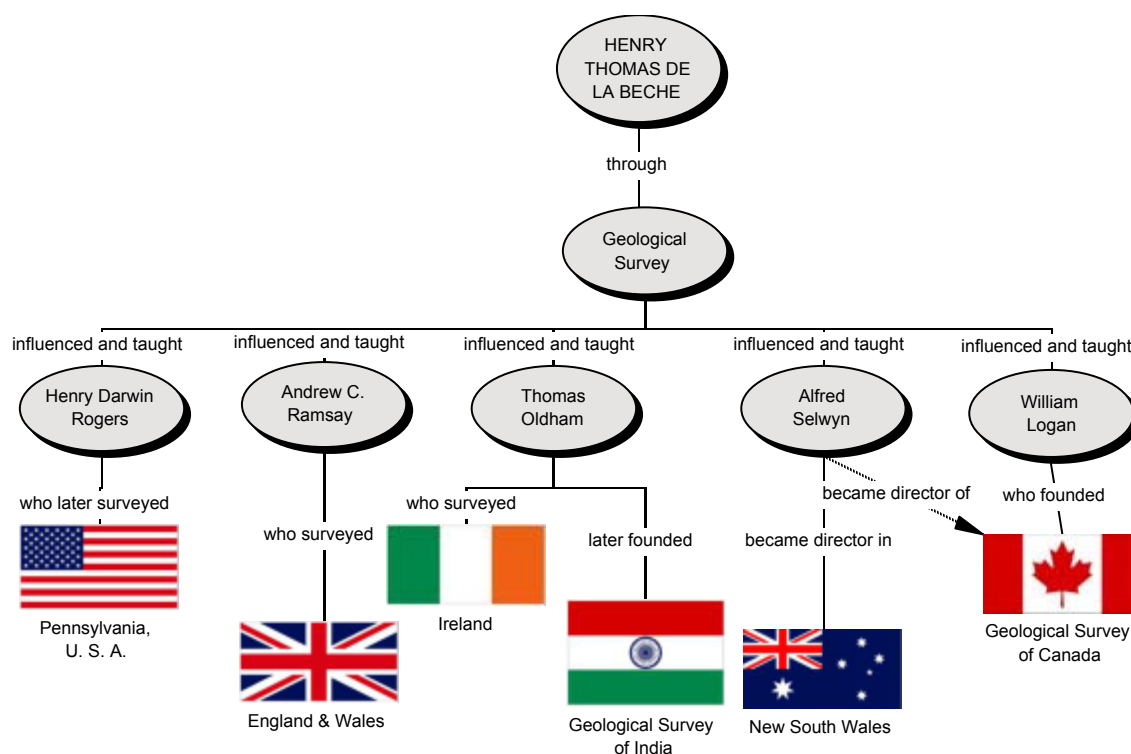


Figure 121: The influence of Henry T. De la Beche around the world through his leadership at the British Geological Survey.

## **Museum of Practical Geology**

Although Henry T. De la Beche's educational bent is demonstrated in the 1845 letter to the local directors within the Geological Survey, there is even earlier documentation of De la Beche using his government position to serve and educate the general population. Soon after he was appointed the first director of the newly formed Ordnance Geological Survey in 1835, Henry T. De la Beche was "forcibly impressed that this survey presented an opportunity, not likely to recur, of illustrating the useful applications of Geology" (De la Beche, 1852, p. 1). De la Beche proposed to Mr. Spring Rice, the Chancellor of the Exchequer, that a collection be assimilated of the countries' various ores and mineral specimens used for road and building construction; persons employed with the survey would have many opportunities to identify and procure various specimens of England's mineral wealth. Furthermore, De la Beche (1852) suggested that the collection be arranged "with every reference to instruction," so that

a large amount of information which was scattered might be condensed, and those interested be enabled to judge how far out known mineral wealth might be rendered available for any undertaking they are required to direct, or may be anxious to promote, for the good or ornament of their country. (p. 2)

De la Beche actually proposed two collections: One collection would illustrate the geology of Great Britain, while the other collection would show the mineral resources of the country (McCartney, 1977). The collection of geological specimens would be sent to the Geological Society of London, while the Board of Public Works would house the mineral resource collection. De la Beche's proposal was favorably received; in 1837, a house in Craig's Court, Charing Cross was made available to the Geological Survey to accommodate the collection of mineral resource specimens. The specimens, as well as models of mines and mining machinery accrued rapidly. This first museum, called the

Museum of Economic Geology, opened its doors to the public in 1841. The Museum of Economic Geology eventually evolved into the Museum of Practical Geology on Jermyn Street, and the Geological Museum at South Kensington (North, 1944).

The Museum of Practical Geology was formally opened, along with the School of Mines, on November 6, 1851. In his inaugural discourse, De la Beche reaffirmed the purpose of the collections:

They are not intended to be mere assemblages of specimens, striking either for their brilliancy, colour, or form. In whatever department they may be found they are intended to be *instructive* with reference to the especial object proposed in that department, and to be employed in *illustration of the teaching by lectures* or other means adopted by those in charge of the different departments confided in them [italics added]. (De la Beche, 1852, pp. 3-4)

The vigilant collection of facts that De la Beche believed should be the goal of geology was carefully preserved with the specimens. The architecture and engineering stone specimens were carefully inscribed: The edifices in which the stone had been used were noted, so that the architect could visit the structure and ascertain the effects of weather upon it. De la Beche even ensured that different building stones were utilized for statuary in the new museum. Ceramics, glass, and metallic minerals were likewise annotated and explained. The various metals, for example, were arranged to “show the various ores of the different metals, their mode of occurrence in the earth, the methods employed in their extraction, and the means used for rendering them marketable” (De la Beche, 1852, p. 7). De la Beche further noted, “Our collections of the mode of occurrence of the ores are very extensive, and great care is taken to make them *effectively instructive* [italics added]” (p. 9). Mining and paleontology were also represented in the collections; there was also a series illustrating rock formation during various geological periods. De la Beche sought to be educational not only by accumulating geological specimens, but also

in presenting the specimens in the museum environment. For those who were seeking more knowledge about geology and its implications, the Museum of Practical Geology arranged samples and included annotations to facilitate learning.

### **School of Mines**

In 1843, England's treasury sanctioned lectures to be given on the practical applications of geology; however facilities were not available, and arrangements for lectures were made only after the Museum of Practical Geology and the School of Mines opened on November 6, 1851. De la Beche (1852) noted at the opening of the facilities that "a system of instruction new to our country" was being inaugurated, and this instruction "tending more especially to illustrate the application of Geology, and of its associated sciences to the useful purposes of life, was early decided" (p. 1). However, eight years had passed from the first approval of lectures to the opening of the facilities on Jermyn Street.

De la Beche's first letter in 1835 requesting permission to amass a collection of specimens had not been accompanied by a similar request for lectures at the museum facility. However, De la Beche was familiar with the geological circles and research in continental European countries; he had translated the papers in *Annales des Mines* specifically to bring the continental European knowledge back to his British contemporaries. Because of his European involvement, De la Beche was also aware that other European countries had mining schools, many of which were established in the late 1700s. Since England's mining industry was managed privately, there was little government involvement. As a result, no government-sponsored mining school had been established in England during the age of focus. It would largely be through the influence of De la Beche that England did establish its first School of Mines in 1851.

While there may have been many influences upon the establishment of the School of Mines, two factors can be identified that shaped its development. Reyment (1996) believed that De la Beche wanted to mold a school along the lines of the Ecole Polytechnique in Paris; De la Beche (1852) also acknowledged that Sir Charles Lemon had established a mining school in Cornwall in 1838 at his own cost, and had offered to fund a proper school if the government would match his donation. Unfortunately, circumstances proved unfavorable at the time. De la Beche would also encounter several difficulties in convincing the government to fund this educational endeavor: Funding for the professors who would lecture posed a problem, especially when no similar professorships in England existed that could provide parallel cases for salary considerations. De la Beche (1850) concluded that the most successful monetary arrangement would be a “moderate fixed Salary with the whole or part of the fees derived from Students” (p. 10).

In the inaugural address, De la Beche (1852) noted that England was behind the continental European countries in the establishment of a mining school:

[T]here existed until now no means in this country for affording needful instruction to those who thus raise so great an amount of mineral matter, to be afterwards employed in affording occupation to an additional and large part of our population; all was left to chance, and the result is well known . . . It is to be deplored that so much of the mass of important facts known to such men has been lost from the want of a system by which it could have been preserved for classification and use in further advance. (pp. 14-15)

De la Beche acknowledged the multi-faceted nature of geology; since applications were diverse, a corresponding broad system of instruction was required. At the new institution, the proposed instruction was divided under various specialists. De la Beche (1852) asserted, however, that science and practice were not categorized separately, and should be viewed as “mutual aids” (p. 21). Students would not be encouraged to divorce

a scientific method from experience; science and practice should be combined “that the largest amount of both may be secured” (De la Beche, 1852, p. 16). Indeed, De la Beche (1852) stated that the school was most concerned that students be taught

the power to discriminate between sound and unsound views, so far as existing knowledge may be available, – taking all care not to neglect or depreciate the information afforded by those whose opportunities may not have sufficiently advanced their power to analyse and extend it. (p. 21)

The elevation of fact over theory, and the cautious approach to new and encompassing theories, was still echoed in De la Beche’s words in the 1850s. De la Beche also added new cautionary statements to his repertoire: He advocated that one action should not be taken without ascertaining the negative effects. In statements that parallel the current debates in geology over the cost to coastal erosion through the United States Corps of Engineers’ control of the Mississippi River, De la Beche (1852) discussed the consequences to estuary harbors by land reclamation.

In early support of miners’ safety, De la Beche (1852) also acknowledged the additional safety factors that would result from a formal mining school; in his typical form, he argued that the compilation of facts could influence the mining directors and save lives:

How many lives would be saved in our collieries [coal mines] if but a fair range of information were afforded to those who too often have the lives of so many of their fellow-workmen in their power. . . every day hundreds of those who labour for our comfort or our profit are at the *mercy of ignorance* [italics added]. (p. 18)

Whereas English society readily accepted the idea of an educational facility for the training of mine administrators, De la Beche’s next proposal would challenge the very strict boundaries of social class. He stated, “[W]e propose to explain by evening lectures to the working men of London, those readily engaged in business . . . such parts of our

collections as may be thought to be usefully interesting to them” (De la Beche, 1852, p. 18). Although De la Beche had managed to transcend the social borders in his transition from elite gentlemen geologist to working professional, others in the upper circles were not willing to invest in an educational program for the working class. De la Beche was viewed as a class-traitor, ready to cultivate disgruntlement among the lower classes of society (Reyment, 1996).

In spite of the problems encountered in the establishment of the School of Mines, Chubb (1958) believed that the scientists gathered by De la Beche were the most brilliant accumulation that ever served in an educational institution of the United Kingdom. Flett (1937) mentioned many distinguished names on the professorial staff, including Thomas Henry Huxley, John Tyndall, John Percy, Gabriel Stokes, and A. W. Hoffmann; he noted that much original research was conducted in the laboratories associated with the school. Eventually, the School of Mines was segmented, with the laboratories and staff transferred to South Kensington.

### **Mining Record Office**

In connection with the Museum of Practical Geology, a Mining Record Office was established in 1840. The office would serve as a repository for plans and sections of working, as well as abandoned, mines. Benefits of such an accumulation of plans included prevention of loss of life, guidance for the outlay of capital, and direction for the ways in which mining should be accomplished. The plans and sections, therefore, would serve to educate mine administrators as to the current and past conditions of mines, and inform their decisions for the future.

De la Beche (1849) was also perhaps one of the first public lobbyists for the miners. He advocated the government inspection of collieries, or coal mines, and

recommended that ventilation be investigated for each mine. Other recommendations included a proper and efficient map of each colliery, and immediate reporting of explosions, whether or not they resulted in loss of life.

### **Summation of Educational Endeavors**

Although De la Beche's promotion of education through his official government position is discussed in separate institutional categories, De la Beche never intended that instruction should proceed through only one method, or include only one subject. He hoped that students would avail themselves of all opportunities presented through the British Geological Survey and the Jermyn Street facilities:

We propose to instruct by means of our collections, our laboratories, our mining record office, our lectures, and the Geological Survey; – thus teaching in the field as in this building, and so that the pupils can become practically acquainted with mining in our various districts, be able to study geology, and those of its applications requiring it, on the ground itself, and so unite, in a manner not hitherto attempted and yet in one for which our opportunities amply provide, a sound combination of science and practice; a combination also kept steadily in view in our laboratories, and in all branches of the instruction upon which it is now purposed to enter. (De la Beche, 1852, p. 3)

Therefore, De la Beche advocated education in context, as opposed to isolated facts and subjects. Ironically, incorporation of this educational suggestion is currently sought today, as teachers attempt to integrate and articulate the curriculum across grade levels and between subjects.

### **The Role of Henry T. De la Beche in Shaping Geological Thought**

When the totality of De la Beche's accomplishments are considered, including his graphic innovations, numerous publications, and educational endeavors, he emerges as a giant among the early geologists. Although he now appears to be a forgotten contributor in modern geology textbooks, De la Beche was highly regarded by his geological



contemporaries. Through his original research, his graphics, texts, and official government position, he helped to shape the direction of early geological thought.

Early in his geological career, De la Beche was an observer within elite geological circles. His first scientific publications were not without merit; he published temperature and depth data for Lake Geneva, as well as fossil discoveries made during his travels. De la Beche also worked with William Buckland and William Conybeare on the identification and interpretation of the fossils retrieved from the Lias cliffs near his home of Lyme Regis. Fowles (1982) declared that these three geologists – De la Beche, Buckland, and Conybeare – were responsible for practically all of the major papers that founded the scientific research based on the Jurassic formations and fossils of Lyme. These papers were well illustrated by De la Beche; he used his artistic skills to present pictorial representations of the fossils to the reader.

De la Beche's membership in the Geological Society of London and the Royal Society ensured his place in the elite scientific circles. In 1824, he translated and illustrated papers in *Annales des Mines* in order to convey geological knowledge from continental Europe to his geological contemporaries in England. The 1830 *Sections and Views* was also published to make geological facts known to the elite geological circle. This book had the highest graphic density (Chapter 6, Figure 117) of any geology text investigated in this research study. In *Sections and Views*, De la Beche introduced the small multiple format to present geological sections; it appears he was the first geological author to do so.

De la Beche launched his first general geological text in 1831, with *A Geological Manual*. This text, too, had high graphic density in comparison with other geology texts released at the time, including Lyell's *Principles of Geology*. Hypothesis testing around

correlation coefficients did show significance at the 0.01 level for relationship between publication year and graphic density, as well as for relationship between publication year and the number of included illustrations. Graphics became more abundant in geological texts as wood engraving became a popular and efficient technique of illustrative reproduction; the general population's interest in natural history and the growth of an educated professional class occurred in the near historical vicinity of higher graphic density in texts. Although changes in the reproduction of illustrations through the technique of wood engraving undoubtedly influenced the number of graphics that De la Beche incorporated into his texts, the fact that his graphic density is higher than comparable texts of the same period supports the claim that De la Beche sought to convey geological knowledge through visual representation, as well as through the printed word. Lyell's 1838 *Elements of Geology* also had high graphic density, but this focus on a larger number of illustrations occurred after he had failed to convert his competent colleagues – such as De la Beche – to his theoretical beliefs; Lyell penned *Elements of Geology* for the general geology text market. It is interesting that Lyell, in this whittled version of his geological beliefs, incorporated the higher graphic density that De la Beche first utilized in *Sections and Views* and *How to Observe Geology*. Most of De la Beche's texts maintained a higher visual component than contemporary texts by other authors.

De la Beche's texts incorporated illustrations similar to those of other geological texts in the same period. Early in the age of focus, illustrations consisted of simple proxy images; many of these pictorial images had low data density and a large amount of chartjunk. However, labeled proxy images and inferred graphic representations began to materialize with the arrival of the early geological texts; Bakewell's (1813) text is an

early example. These illustrative forms were in place when De la Beche began his publication journey, and he tended to utilize many of the same types of illustrations as his contemporaries. While most of De la Beche's graphics were bivariate and of medium data density, his incorporation of chartjunk was generally low. The style of his graphics may have been influenced heavily by the limitations of the wood engraving technique for fine detail; earlier lithographs tend to have greater data density, and include more variables. De la Beche did add some graphic innovations to his texts, including the small multiple formats for sectional views (*Sections and Views*, 1830), and the small vignette scenes from deep time (*A Geological Manual*, 1833a). He also began incorporating more and more general diagrammatic sketches for visual teaching tools, as opposed to pictorial and inferred representations of specific scenes and objects.

Other De la Beche graphics affected the emerging geological science as well. *Duria antiquior* provided the first glimpse into the ancient life represented by the fossil bones and coprolites recovered from the Lias. Today, ancient representations are commonplace, and most students identify ancient dinosaur reconstructions by scientific names. De la Beche's reconstruction, however, mandated that he first understand the scientific information interpreted from the fossils, and second, project his understanding back in time to reveal an extinct ecosystem. The unusual aquarium viewpoint also attests to De la Beche's imagination and creativity; without an existing system on which to base his view, his artistic mingling of science and inventiveness was incomparable. *Duria antiquior* greatly influenced the geological community; Rudwick (1992) documented numerous examples of geologic illustrations that were based upon, or borrowed from, De la Beche's model. Buckland likewise recognized the value of *Duria antiquior*, and utilized it as an innovative teaching graphic in his geology classes at Oxford.

The scientific caricature was also an unusual graphic form effectively utilized by De la Beche. Leddy (1981) acknowledged that some colleagues may have interpreted the caricatures as immature and disrespectful, but De la Beche was able to successfully attack the grand theories and pompous attitudes of some of his geological contemporaries through them. Lyell's belief in non-directionality for the earth's evolution, Agassiz's glacial theory, Lyell's uniformitarianism, and Lyell's and Sedgwick's staunch rejection of De la Beche's early field work in Devon were all topics that were attacked with the full force of De la Beche's pen. De la Beche undoubtedly used the cartoons to expose the inconsistencies of his rivals, and sway his colleagues to his position. Not all of the caricatures were as barbed, however. "A Coprolitic Vision" may question Buckland's obsession with fossilized feces, but the humor is light.

Unfortunately, absolute numbers of distributed caricatures are unknown. De la Beche did imply in a letter to William Buckland that the distribution of "Irregularities of Sol," which attacked Agassiz's glacial theory, was minimal at 20 to 25 copies. The total number of copies of *Duria antiquior* is likewise unknown. Although a relatively expensive lithograph, its influence was great, with copies reaching continental Europe. Buckland furthered the influence of *Duria antiquior* with incorporation of the scene in his classes at Oxford. Adam Sedgwick, as professor of geology at Cambridge, also advanced De la Beche's graphic influence by inclusion of De la Beche's graphics in his classes; one particular letter asks for De la Beche's Welsh sections for a lecture (Sedgwick, 1843). However, De la Beche's most bountiful – and perhaps most effective – publications were his general geological texts. With several English editions, and French and German translations, *A Geological Manual* provided a general geological education for many readers.

Henry T. De la Beche also had opportunities to influence early modern geological thought beyond his texts and graphics. When De la Beche was named the first director of the newly created Ordnance Geological Survey in 1835, he would promote government support of geology education through many different venues. Woodward (1911) acknowledged that the first governmental geological survey of a country was established primarily through De la Beche's efforts. Indeed, in an early persuasive document, De la Beche enumerated the reasons geological mapping should be supported, and noted that in other countries, "the question of *cui bono* as it refers only to immediate pecuniary advantages, have never been raised," with geological maps providing "highest value to the agriculturalist, the miner, the builder, and the road-maker" (De la Beche, 1832e). His persuasions to the government eventually proved successful, and directly affected the establishment and course of the British Geological Survey. Furthermore, the dispersion of those who worked and learned under De la Beche in the Geological Survey brought his views and methodology worldwide.

The Devonian controversy was a major dispute in the Golden Age of Geology, and De la Beche was heavily embroiled in all of its debates. When the controversy concluded, none of the original beliefs had survived unscathed; De la Beche, Sedgwick, and Murchison, from today's scientific perspective, were all only partially correct in their original hypotheses. De la Beche's involvement in the argument, especially his insistence that field observations be utilized, helped lead to a successful close. Leddy (1981) suspected that De la Beche "accelerated the process of discovery and inspired sound scientific habits in his contemporaries which were essential for the credibility of a science in its infancy" (p. 41).

In his position as director of the Geological Survey, De la Beche proved he was an extraordinary organizer and problem solver. His abilities to promote geological education – amazingly, though government funding – were unique. Flett (1937) succinctly stated that De la Beche had “especially well developed the sense of fathoming the official mind, and knew perfectly what arguments were likely to carry most weight with administrative persons. This is really a natural gift which many scientific men completely lack” (p. 55). When De la Beche was dismayed with the lack of government support for mining education, he managed to use national pride to his advantage. De la Beche proposed compromises that were manageable by all parties involved; for example, funding of lectures at the School of Mines was to be accomplished through a small salary provided by the government, but supplemented with pay by the attending students. De la Beche also seemed to insightfully know the limitations for successful requests: He usually began with small, inexpensive proposals. When these projects were fruitful, expansion of his initial proposal was inevitable. Perhaps the culmination of De la Beche’s professional career was the official opening of the School of Mines on November 6, 1851. The location of the facility – a prime Jermyn Street site that backed on to Piccadilly – was no small fete. Prince Albert’s attendance at the opening ceremonies also attested to event’s perceived importance in an official, as well as scientific, capacity. In the end, this was the first institution constructed in Great Britain solely for the advancement of science. News coverage of the Museum of Economic Geology (Museum of Economic Geology, 1848), and later the opening of the Museum of Practical Geology (The Museum of Practical Geology, 1851) also underlined the importance of De la Beche’s geology education contributions in the form of museum

exhibits. Knell (2000) declared that De la Beche wielded more influence on the institutionalization and professionalization of geology than any other person.

### Implications for Geoscience Education

A prominent geologist during the age of focus, Henry T. De la Beche influenced the course of early geological thought through his original geological research, publications, graphics, and official position as first director of the eventual British Geological Survey. De la Beche's first journal publication in 1819 marked his entry into the scientific realm of geology that would not come to an end until his death in 1855. At the dawning of geology as a science, De la Beche's involvement was great, and his accomplishments numerous. Although he is no longer mentioned in general geology textbooks and is a forgotten giant in geoscience classrooms, Henry T. De la Beche and his geological graphics deserve a role in geoscience education. The introduction of De la Beche and his geological contributions offers several advantages to the geology curriculum, including enrichment through the addition of historical context, and visual enhancement through incorporation of De la Beche's graphic innovations. The utilization of these historical endeavors and innovative illustrations through the Theory of Human Constructivism can enhance meaningful learning, and encourage student understanding of the nature of the scientific enterprise.

### **History of Science: De la Beche's Contributions for the Classroom**

The inclusion of the history of science in the curriculum offers the possibility for promotion of more meaningful learning. Matthews (1994) advocated the incorporation of history and philosophy of science in science teaching because it has the potential to enhance critical thinking, humanize the curriculum, and integrate social, political, and cultural environments with scientific theory. Duschl (1994) has further noted that the

history of science is important for showing the restructuring and reorganization of scientific knowledge as new information becomes available. For early modern geology, events in Henry T. De la Beche's geological career offer insight into the dynamic nature of the science, and the social and cultural influences on its evolution. Slices of his historical interactions can further illustrate the important debates in the Golden Age of Geology, avoid Duschl's (1990) final form science, and offer De la Beche as a role model who moved beyond the strict social and gender barriers of his day.

**De la Beche and the Nature of Science.** Henry T. De la Beche, like many of his contemporaries, was wary of the grand theorizing promoted by Hutton. De la Beche alleged that geology was too young a science, and mega theories rested on inadequate evidence. Therefore, he promoted the collection of facts, which would remain valuable to the future researcher long after the current theory had been replaced. According to De la Beche, data collected in the field should be accurately portrayed and represented in order to retain its usefulness in support or denial of changing explanations.

Henry T. De la Beche was one of many geological contemporaries who met Charles Lyell's support and development of uniformitarianism with great skepticism. Uniformitarianism, as the mechanism scientists use to explain the formation of most of the earth's observed features, is now considered to be one of the pivotal constructs in geoscience education. Although it is usually presented in modern geology texts as a principle whose validity and usefulness were immediately recognized, history does not reflect an encompassing embrace of the construct upon its proposal. Introductory geoscience students are not often given the context and milieu of debate in which this central idea of geology evolved. However, the exchanges between the uniformitarians and catastrophists were important in shaping geological thought, and should be made



available to students. Catastrophists contributed to the evolving science of geology, and were not entirely incorrect in their beliefs: A form of catastrophism is accepted today for the mass extinction events at the end of the Cretaceous, marking the end of the reign of the dinosaurs.

Henry T. De la Beche's actions during the ensuing debates of uniformitarianism can provide students with glimpses into the development of science and scientific methods. De la Beche questioned Lyell's postulates, noting that Lyell did not adequately explain occurrences witnessed in the field. Indeed, some of the data specifically contradicted Lyell's beliefs. Furthermore, the total theoretical package supported by Lyell and the constructs accepted today are not without differences. Many of Lyell's specifics have been altered in the course of geological research and debate, including the belief in non-directional evolution of the earth so cleverly attacked by De la Beche (1830a) in the caricature "Awful Changes."

Henry T. De la Beche did exhibit scientific habits of mind, however. He acknowledged that a scientist should change his or her mind as new facts emerged that contradicted current beliefs. In spite of his initial dislike of Lyell's theory, De la Beche did eventually gravitate toward acceptance of some of Lyell's claims and attitude toward science (Gillispie, 1959). Other evidence of De la Beche's questioning mind and changing views are documented in his exchange of letters with William Buckland. Although Buckland was a friend, De la Beche's views on diluvium – the term used for rocks deposited by massive ancient floods – eventually digressed from Buckland's proposals. De la Beche was quite clear that he would not support Buckland's views when he commented on Buckland's suggestions for his paper:

[E]xcuse me if I say that I am not so contented with your theoretical alterations, and had the paper unfortunately been printed with them, I should

have felt myself compelled, though reluctantly, to have disowned it, in some other publication – You seem, my dear Sir, not to be aware that my ideas respecting the value to be attached to diluvium, as resulting from many sudden and violent causes have completely changed of late, I may be wrong, but it must be quite clear that with this altered opinion, I could not authorise the publication of my Nice paper, with your theoretical views attached to it – they therefore will be all removed and as probably you will still wish to publish them, you had better add them as objections to my views in your Appendix. (De la Beche, 1829a)

De la Beche further remarked that much unpublished information, brought forth by von Buch and Elie de Beaumont, contradicted some of Buckland's views, and it was "a pity that you should not have been acquainted with them before you printed your appendix" (De la Beche, 1829a). Buckland did not seem slighted, however. While he defended the term "diluvium" as specialized and applying only to "Deposits that resulted from a violent and sudden irruption of water," he noted that he was "glad you are here to reject any change in your Paper that I may have suggested" (Buckland, 1829).

Not all differences of opinion between geologists were solved as pleasantly. The Devonian controversy, in which De la Beche was a primary participant, is an illustrative example of how geological disagreements also involve the social influences and personalities of the participants. It is highly descriptive of how the geological timescale is a human construct, which is constantly modified as new evidence becomes available. Although De la Beche's involvement in the debate promoted additional accumulation of field evidence and scientifically benefited the eventual conclusion, he also was personally affronted by the attack on his professional geological mapping skills and vehemently defended his position.

Henry T. De la Beche's historical involvement offers further value to the modern geoscience class in his support of a combination of science and technology. De la Beche acknowledged that geology was a conglomeration of many different sciences, uniquely

pooled. The suggestions he imparted in his opening address for the Museum of Practical Geology and the School of Mines are instructive to teachers as well as students: A scientific discipline does not exist in isolation, but relies on many different fields and elements for its successful application (De la Beche, 1852). Although schools usually compartmentalize knowledge to be taught into discrete courses, true scientific endeavors do not segregate knowledge. De la Beche's historical actions illustrate the integration of the geology with technology, mathematics, engineering, architecture, and chemistry.

**De la Beche: Contravening Social and Gender Barriers.** Henry T. De la Beche's involvement in early modern geology exposes the nature of the scientific enterprise and provides students with a glimpse of the interactions and struggles involved in the evolution of the science. However, historical episodes in De la Beche's life offer additional benefit to the geoscience classroom: Many incidents demonstrate a move across the strict social and gender boundaries of the day.

As a prominent geologist during the age of focus, Henry T. De la Beche influenced and was influenced by the changing society of his time. The period from 1788 through 1840 was one with very distinctive social classes; the status of the individual determined the role that the individual might play in the emerging science of geology, in spite of any outstanding traits or skills the individual might possess. Gender roles were also mandated, with women being allowed very little participation in the scientific enterprise. De la Beche, as a gentleman of social standing, was able to join illustrious groups such as the Geological Society of London and the Royal Society; he was able to participate fully at the upper levels of the science, including publication of his views through texts and papers. However, with the collapse of his financial revenues from his Jamaican interests, he was forced to earn a living as a professional geologist. He

successfully straddled both the elite circles of science, and those of working professionals. As the first director of the Geological Survey, De la Beche was not content to solely map the geological formations of England; he also promoted government-sponsored geological endeavors.

The Museum of Practical Geology, School of Mines, and Mining Record Office included educational components in their activities. What is most unusual, however, is that De la Beche advocated geological education for everyone, including the miners and general population outside the elite social circles. It is difficult to ascribe how much of the educational events were due to the evolving nature of the science and society, and what percentage was through the personal beliefs and efforts of De la Beche. However, De la Beche's role in the establishment of institutions with geological purposes is undeniable; he accomplished tremendous advances for geological education. He also served as a role model for future generations of geologists: He was willing to overlook social status in order to achieve educational and scientific goals.

De la Beche also emerges as a role model for gender equity in the 19th century. He first met the female fossil collector, Mary Anning, when he moved to Lyme Regis. Common paleontology interests undoubtedly fueled their friendship. Although Mary Anning was of lower social status than De la Beche, the two obviously maintained their association: De la Beche published his findings on some of the fossils he analyzed that were collected by Mary Anning. When Anning experienced financial difficulties in 1830, De la Beche drew the first scene of deep time, from an aquarium view, as a fundraiser for her. Anning mentioned De la Beche in her letters. Upon her death, De la Beche, as President of the Geological Society of London, wrote the only obituary ever afforded to a nonmember. In his association with Mary Anning, De la Beche moved

across both gender and social constraints in the Golden Age of Geology. His incorporation into the geoscience curriculum could provide a much-needed role model in the science: As a privileged male, he valued and acknowledged contributions from the marginalized scientific scholars of the day. Henry T. De la Beche publicly recognized and honored contributions from women and those in lower social classes.

### **De la Beche Graphics**

The historical investigation conducted in this research study sought to determine the types of graphic forms of knowledge representation incorporated in early geology texts, and whether or not some of these graphics have possibilities for improving geoscience education today. In the late 1700s, the few graphics utilized in texts were simple proxy images; they were low in data density, and heavy in chartjunk. By 1840, the end of the Golden Age of Geology, graphic forms had progressed to labeled proxy images, inferred representations, and small multiples. Diagrammatic images were also used to represent general conditions, as opposed to illustrations highlighting specific sectional views or objects. Geology was still in a pre-graph era, and relatively few examples of mathematical representations exist. However, Rudwick (1976) noted that by 1840, visual forms of representation in geology were not only decorative; they had “become an essential part of an integrated visual-and-verbal mode of communication” (p. 156). Although the geologists of the day did not recognize the significance of the united visual and verbal modes of communication, Paivio’s (1971, 1991) memory research has supported the effectiveness of this combination.

Many of the graphics produced by Henry T. De la Beche have potential for successful incorporation in the modern geology classroom. As a skilled artist, De la Beche was able to draw his own illustrations, and wield more control over the final

product than his contemporaries. His texts also have higher graphic density than most of the other texts examined. De la Beche designed and drew innovative graphics that still have relevance in the modern classroom: The small multiple sectional views, the educative diagrams, the vignettes from deep time, and the caricatures can enhance the geology curriculum if successfully incorporated to provide meaningful learning.

**Small Multiple Sectional Views.** Henry T. De la Beche appears to have been the first geological author to incorporate a form of Tufian small multiples in his texts. In *Sections and Views*, De la Beche presented colored sectional views as small multiples, with a single color key at the bottom of the plate. The consistency of the scale, coloration, and labeling enable the reader to quickly gather data from the small multiple frames after deciphering only one design format. In De la Beche's graphics, the variable that changes between the sections is geographic distance, while rock lithologies and formations are uniformly represented. These small multiples are very efficient ways to present large amounts of data in an easily decipherable schema. De la Beche's small multiples can introduce students to this early use of effective graphic representation. Once students have mastered interpretation of the small multiple, learning can be extended and personalized by student construction of small multiple graphics.

The small multiple is underutilized in geological education. However, it can easily be tailored for various types of data representation. In introductory geology classes, the small multiple format can effectively represent a variety of information, including coastal erosion changes through time, fluvial migration, and volcano evolution. The coded small multiple, introduced in Chapter 6, can also be easily employed in introductory classes to represent mineral characteristics, and to distinguish various types of igneous rocks.

**Diagrammatic Representations.** Diagrammatic representations made an appearance after the introduction of labeled pictorial images and inferred depictions. The shift from a specific representation to a general diagram often reflects a change in the author's purpose: Instead of illustrating a specific *example*, the author wishes to *educate* the reader as to a general principle. *Annales des Mines* (1824a) and *Sections and Views* (1830e) had education as their purpose: De la Beche wished to educate his colleagues about the geological research in continental Europe, as well as accurately represent data from the field to educate through factual illustrations. However, most of the graphics in these texts represented specific scenes or objects in nature. As De la Beche wrote more general geological texts, the graphics shifted from labeled proxies and inferred representations to a greater number of general diagrammatic representations. Many of these illustrations are accurate, and still have value as visual tools through which geoscience education can be facilitated. De la Beche's illustrations that portrayed the dangers of vertical exaggeration in sectional views were unique when introduced in *Sections and Views* (1830e). However, the diagrams were still being cited over a century later (Mather & Mason, 1939), and are referenced today in modern stratigraphy classes (Lock, personal communication, January, 2002). Many of De la Beche's illustrations have this same potential, including the graphic in *Researches in Theoretical Geology* (1834b) that exhibits crustal relief, and the strike and dip illustration in *How to Observe Geology* (1835). Classroom utilization of De la Beche graphics not only provide accurate and innovative illustrations of general geological principles, but they also offer opportunities to integrate the historical aspects of the science into the classroom. This has the potential to make the geoscience classroom more interesting, as well as integrated, for the students.

**Scenes from Deep Time.** Martin Rudwick (1992) claimed that De la Beche's pioneering scene from deep time, *Duria antiquior*, was of supreme historical significance. Not only was this the first true reconstruction of an ancient ecosystem, but the viewpoint of the illustration was novel as well. De la Beche's geological contemporaries realized its educational importance; Buckland (1831a) reported incorporating *Duria antiquior* in his Oxford classes. The educational value of the ancient scene exists even now. Today's students have been exposed to ancient reconstructions of dinosaurs, with these so commonplace that the process behind the illustrations is overlooked. However, it is important for students to understand the data and analysis behind such a reconstruction; these scenes are not fanciful, but are based on scientific methodology. De la Beche's scene has potential to illustrate the sea reptiles of the Jurassic, and provide glimpses of the procedure through which the graphic was created. Furthermore, the depiction of the fossilization process of eventual coprolites provides interest and humor. Once the process involved in ancient reconstruction is understood, students can apply this knowledge in creating their own scenes from deep time. *Duria antiquior* has potential in the modern geoscience classroom to promote higher order thinking through analysis, as well as through synthesis.

**Scientific Caricatures.** The scientific caricatures drawn by Henry T. De la Beche possibly possess the greatest potential for meaningful learning in the geoscience classroom. This unusual visual form of knowledge representation appears to encapsulate the early theoretical debates between the catastrophists and uniformitarians. Through the deliberate exaggerations of key aspects of the issues they challenge, the De la Beche caricatures give the viewer an unusual window on the integration of geology, culture, history, and politics of the Golden Age of Geology. Their dual purpose – for stimulus of



debate as well as comic effect – provide a rich, multi-textured, and layered complex of information, representing what Tufte (1997) has termed a “visual confection.”

Henry T. De la Beche challenged Charles Lyell’s beliefs through scientific caricatures in several ways, including direct attacks on the theory’s promoter, the presumptuousness of the proposed mega theory, the variations in ocean levels, the uniformitarianism versus catastrophism debate, and the non-directionality of the earth’s evolution. All of these themes are represented in the sketches from De la Beche’s (circa 1830b) field notebook; however, the non-directionality of the earth’s evolution was selected as the theme of the published scientific caricature “Awful Changes.” The uniformitarianism versus catastrophism theme was also published in a scientific caricature; “Cause and Effect” questions the development of a large U-shaped valley by the small meandering stream coursing through it.

Not all of the published scientific caricatures directly attacked Lyell’s theories; De la Beche applied his artistic skills to other geological disputes of the day. He questioned the glacial theory of Agassiz through “Irregularities of Sol,” and comically depicted William Buckland’s investigations into fossilized feces in “A Coprolitic Vision.” De la Beche laughably highlighted illogical implications, while maintaining a serious challenge to the hypotheses that underlined the assertions. He produced a valuable visual record of the geological community’s reactions as new theories were proposed, and evolved.

Unfortunately, scientific caricatures have been “lost” over time from our science-learning repertoire; teachers do not use them, or require students to construct ones like them in geoscience classrooms today. However, caricatures potentially offer numerous student-learning benefits. Scientific caricatures can be employed to illustrate the

dynamic nature of geology. The suggestion, debate, and ensuing modifications to theoretical proposals are grandly illustrated in De la Beche's caricatures, and illuminate an historical perspective that is often missing from the geoscience classroom. Cultural, political, and social influences are grandly exposed, revealing a true nature of the scientific enterprise to students. Classroom interpretation of De la Beche's scientific caricatures facilitates student understanding and application of scientific concepts. Furthermore, scientific caricatures have the potential for incorporation as assessment tools; students can demonstrate a deeper understanding of key geological debates through analysis of existing caricatures, or creation of their own scientific caricatures.

### **Theory of Human Constructivism: Methods for Classroom Incorporation**

The incorporation of Henry T. De la Beche and his innovative geology graphics in the introductory geoscience classroom offers the potential to improve geoscience education; this assertion is supported by research into the dual coding of information, as well as investigations into the importance of historical perspective in the science classroom. Since geology is a very visual science, graphic representations are abundant in introductory texts. Research conducted by Paivio (1971, 1991) and his associates support the dual coding theory in which the value of knowledge presentation in simultaneous visual and verbal formats is confirmed. Matthews' (1994) research supports the inclusion of the history of science in the science classroom. However, the manner in which De la Beche and his illustrations are introduced to the geology classroom will determine whether meaningful learning is achieved, or whether students view the historical slices and graphics as additional material to be memorized, and then discarded. Learning tools should complement learning goals. Whereas transmission models and rote memorization of standards-based content may seem to be the quickest route for students to succeed in

test-saturated classrooms, it is a dismal failure as a strategy for encouraging student understanding and constructing more advanced and integrated conceptual frameworks. In contrast, the Theory of Human Constructivism advocates quality over quantity, meaning over memorization, and understanding over awareness (Mintzes, Wandersee, & Novak, 1998). The reform policy principle of “less is more” encourages teachers to provide meaningful learning situations in order to facilitate knowledge restructuring and conceptual change in their students, but this does not happen as often as it should in introductory geoscience classrooms. When the meaning-making capacity of students is engaged, students tend to incorporate more and more knowledge into increasingly powerful conceptual structures. Instead of simply reciting memorized material, students are empowered to evaluate and challenge knowledge claims and value claims. The assessment of students’ conceptual change cannot occur through the formalized, dichotomous comparisons of the past, but through vehicles that probe for and reinforce meaningful science learning (Mintzes, Wandersee, & Novak, 2000).

The Theory of Human Constructivism provides guidelines for the successful utilization for De la Beche’s innovative graphics and the history of science in the classroom, as both teaching and assessment tools. Techniques that involve students’ active participation and allow students to connect new knowledge with their existing conceptual frameworks are desirable as vehicles for meaningful learning. Although endless possibilities exist in which Henry T. De la Beche and his geological illustrations can be utilized in the classroom, some suggestions are discussed below. In addition to general considerations advocated by the Theory of Human Constructivism, historical readings and analyses, historical debates, historical letter writing strategies, Interactive Historical Vignettes (IHVs), and concept mapping offer specific techniques that promote

successful integration of new knowledge into students' conceptual frameworks in the geoscience classroom.

**General Considerations.** The Theory of Human Constructivism offers basic considerations for introducing new material in the classroom. A simple premise is that students cannot simply be *told* new information; students must be *involved* and *construct* knowledge with the new information. Therefore, when Henry T. De la Beche's graphic innovations are utilized in the geoscience classroom, students must be given adequate time to study and analyze the graphics. With small multiples, students need sufficient exposure to the visual representational form before they are familiar enough to construct their own small multiple graphics. Teacher modeling is essential. Diagrammatic representations must also be taught; teachers cannot expect students to extract meaning and data from graphics if they have never been trained how to do so. In order for students to successfully incorporate these new illustrations into their knowledge structures, they must have ample opportunities for integrating the new knowledge within their existing frameworks.

Learning a concept in isolation is not desirable; we expect our students to apply knowledge gained to new situations. However, Haskell (2001) identified hours of practice and drill as requisite for transfer of learning to occur; most transfer failure in the classroom is caused because the material was not sufficiently practiced, and therefore not mastered. In fact, there is a direct and continuous correlation between the number of hours a person has practiced and his or her expertise (Haskell, 2001). Transfer is also more likely to occur if the learner has a highly integrated conceptual framework, and if the environment in which learning occurs engages the affective domain of the learner.

Students' understanding of the historical background of the information is also vital for transfer of learning to occur (Haskell, 2001). The incorporation of the historical background in which the graphic originated can integrate geological information with the scientific context, culture, and politics of the day. This is especially applicable with De la Beche's scenes from deep time and scientific caricatures. The construction of *Duria antiquior* provides a glimpse into the gender and social biases of the 19th century; however, the history also offers De la Beche as a role model willing to move beyond the strict social boundaries of his time. An understanding of the history of De la Beche's scenes from deep time serves to enliven the curriculum. When students understand the process by which ancient scenes were created, they are better able to integrate science and creativity in order to produce their own inferred ancient ecosystems.

Incorporating the history involved in De la Beche's scientific caricatures also appears to have the potential to increase depth and breadth of student understanding in the geoscience classroom; the caricatures present opportunities for construction of powerful, integrated, and encompassing knowledge structures. Students exposed to the historical debates involved in De la Beche's scientific caricatures require understanding and application of scientific concepts – such as uniformitarianism and glacial theory – for their interpretation. Learning becomes less superficial as students gain a deeper understanding of the nature of science and the evolution of theories. However, teachers cannot expect students to achieve this stage rapidly, nor can they expect students to achieve deeper meaning without guidance. Caricatures should be introduced in the classroom over several months; the teacher's probing questions can direct students' interpretations for initial scientific caricatures examined. The teacher should always orient the student, and repeat the orientation frequently to circumvent student frustration.

With practice, students will acquire the ability to critically examine these cartoon-based diagrams and extract theoretical and social issues.

The historical context of De la Beche's diagrams, as well as slices of his interactions during the Golden Age of Geology, can be incorporated into the geology classroom in a variety of ways. Some techniques that have been developed through the Theory of Human Constructivism are historical readings and analyses, historical debates, historical letter writing strategy, and Interactive Historical Vignettes. All of these methods offer possibilities for introductory geology and earth science classes.

**Historical Readings and Analyses.** Incorporating historical texts and information into the scientific curriculum can be accomplished through an assortment of techniques. However, one of the most common methods of inserting information from historical texts is by simply paraphrasing the original material and reporting it to the students. This method obviously has several drawbacks. Students should be allowed access to the original works written by the great researchers and theorists elevated by the science; however, this is not always easy to do.

Some of De la Beche's original texts offer the potential to increase student awareness concerning the growth of early modern geology. In particular, De la Beche's *Sections and Views* (1830e) and *How to Observe Geology* (1835) can provide students with general educative diagrams, as well as documentation for the popular view of the science – elevating facts above theories – during the Golden Age of Geology. *Researches in Theoretical Geology* (1834b) attempted to effectively synthesize geology with other sciences; it emphasizes the integration and articulation between subjects that are promoted today.

Historical texts and accounts from the Golden Age of Geology can also be very valuable for illustrating the *nature of geology* (NOG), and how many geologists of the day made theoretical reversals in the face of new evidence. De la Beche, Lyell, and Sedgwick all modified their views during the Devonian conflict. William Buckland also abandoned his Diluvium theory as new evidence became available. Indeed, Buckland became a major proponent of Agassiz's glacial theory when Agassiz convinced him, through examples in nature that authenticated past glacial activity. The rapid publication of geological opinions in the mid-1800s provides texts that illuminate the changing opinions of the day; these publications show how progress is made in the geology, and reveal how the science comes to a consensus.

Original texts not only provide scientific detail and an understanding of the theoretical mindset, they also add flavor to the content presented. However, teachers should carefully plan the inclusion of older texts in the classroom. Historical readings should not be infrequently inserted into a curriculum, with the expectation that students easily read and understand what is presented. Organizational patterns and writing styles are very different in older texts, and reflect the grammatical conventions of the period in which they were written. It will undoubtedly require time for students to read and *understand* the older texts; style differences make the texts more difficult to comprehend. However, with careful and consistent incorporation, older texts are a valuable reference source in the classroom, for both scientific and social information.

**Historical Debates.** Teachers can utilize reenactments of history in order to enliven the classroom environment. The biography of Henry T. De la Beche offers an interesting and illustrative example that would facilitate student understanding of the nature of geology, the artificial nature of the geologic time line construct, and the role of

personalities and social constraints in early modern geology. The Devonian conflict, as a major debate in the Golden Age of Geology, offers an ideal example of how new facts modify the existing scientific knowledge base. Students can be introduced to this argument through historical resources, secondary sources (Rudwick, 1985), and Internet websites. A culmination of the learning activities can be the performance of the actual debate in the classroom. Students in cooperative learning situations can be assigned to research a participant in the conflict, support the position of the participant with the available evidence, and defend the position in front of a classroom jury. Requiring each student to declare a winner of the debate, and defend his or her position in a brief essay, can extend learning. Teachers can also encourage deeper thinking by altering the situation: If the evidence supporting the participants' claims changes, students evaluate the possible modifications from the actual historical outcome.

**Historical Letter Writing Strategy.** Geologists in the age of focus communicated with each other outside of geological society meetings through the written page. The developing visual language of the science was obvious in their periodical publications and texts, as well as within their letters. Letters written by De la Beche, Conybeare, and Buckland are often illustrated with sections, fossil depictions, and diagrams to clarify the text. These very visual letters could be introduced to students in order to demonstrate the observational and communicative powers of early geologists. Students can then be encouraged to write letters to each other, visually and verbally exchanging geological information they observe in their own communities. Teachers can assign a relevant geological topic to be discussed. Students can then come to consensus through an exchange of letters, which incorporate both visual and verbal data.



**Interactive Historical Vignette.** The Interactive Historical Vignette (IHV) was developed by James Wandersee to address the need for an efficient and effective means to include the history of science in the science classroom (Wandersee & Roach, 1998). The IHV is designed to present a single aspect of the nature of science while utilizing a brief amount of class time (10-15 minutes). Since it is impossible to incorporate in-depth historical background for every topic, the IHV is intended to present a brief slice of history. Students who are interested in probing more deeply into the subject are given reference lists through which they can thoroughly explore the topic. Teachers who regularly utilize the IHV format effectively bring historical perspectives into the classroom with little time consumption. After appropriate modeling, the teacher can assign historical characters to cooperative learning groups for construction of IHVs.

There are many aspects of Henry T. De la Beche's life that lend themselves to vignette presentation. Godley and Wandersee (2002) developed an IHV to illustrate some scientific habits of mind through De la Beche's interaction with Mary Anning. Appendix O reproduces the vignette. The vignette is brief and requires little class time; however, suggestions for extended learning were also presented, including a classroom poster contest and a bookmark with additional Anning references.

**Concept Mapping.** Concept maps hierarchically organize and represent knowledge through propositions, or concepts that are connected to each other through a labeled link. Students first must choose a superordinate concept, and select the important subconcepts or subconstructs to be mapped. Elimination of the extraneous information is important, as the final map should be limited to no more than fourteen total concepts. The superordinate concept tops the hierarchy; the organization mandates that the map be read from top to bottom. Cross-links, or labeled links that bridge across the map's

hierarchy, are sometimes evidence of higher order thinking and moments of insight.

Although concept maps at first glance may seem easy to construct, development of sound organization and effective linking words requires more than a superficial understanding of the subject to be mapped.

Proficiency in concept mapping is not immediate, however; teachers must introduce and model the technique, and provide students with numerous opportunities in which to master the process. In general, it is recommended that students construct at least 10 maps over a two-month period before competency is achieved (Wandersee, 2000). The series of concept maps produced by a student serve as a record of the learning process, as well as documentation for conceptual changes that may have occurred.

Concept maps lend themselves to representation of De la Beche's history. For example, the interactions between geological participants in the Devonian conflict can be hierarchically mapped to expose the influences of society, culture, and politics. Learning may be improved in the classroom when verbal transmission of knowledge is linked with these visual representations (Paivio, 1991); Robinson (1993) also claimed that diagrammatic representations that were self-constructed helped students in their retention of knowledge.

**Assessment.** Often assessment techniques fail to adequately sample and measure the great variety and diversity in student understanding, resulting in low "mode validity" (White & Gunstone, 1992). De la Beche's graphics – the small multiples, diagrammatic representations, scenes from deep time, and especially the scientific caricatures – offer the potential to increase the mode validity of current geoscience tests by assessing a richness of meaning. Assessment should be conducted through a variety of approaches in order to effectively ascertain increased student knowledge and conceptual change; De la

Beche's innovative graphics can be employed to expand the diversity of methods for probing understanding. In addition to the representation of geological information, the illustrations can also offer students the visual opportunity to extract and critically evaluate socially embedded scientific knowledge claims. De la Beche's graphics can be used in an assortment of assessment approaches, including the production of concept maps that represent the structure of the illustration, the composition of captions for scientific caricatures or scenes from deep time, essays of explanation, and the scientifically correct matching of captions and identified details within graphics.

## Chapter 8: Conclusions and Implications for Future Research

Henry T. De la Beche was a geological participant of major importance in the Golden Age of Geology. He began his geological career in the elite circles of gentlemen who leisurely pursued the science, and published original research in periodicals based on his investigations near his home of Lyme Regis as well as abroad. De la Beche's vehicle of publication began to shift as he authored books: Two early innovative texts, *Annales des Mines* (1824a) and *Sections and Views* (1830e), were produced in order to educate De la Beche's geological contemporaries as to the research being done in continental Europe, and the facts observed by De la Beche in the field. The journey into text publication continued, but a shift in focus occurred. In the 1830s, De la Beche entered the general textbook market, and his targeted readers changed from the elite gentlemen in the geological societies to the general population. *A Geological Manual* (1831) and *How to Observe Geology* (1835) were two of the resultant texts that provided general geological education to the reader. The visual nature of De la Beche is evidenced by his texts, which provide more illustrations and result in greater graphic density than most contemporary texts of his colleagues. De la Beche also developed and utilized several innovative graphic forms, including the small multiple for sectional views, scenes from deep time, caricatures, and diagrammatic representations to provide illustrations for general geological concepts.

When Henry T. De la Beche's income began to dwindle from his Jamaican plantation interests, he sought government support for a geological mapping project he had undertaken. The government agreed to support De la Beche's completion of the mapping venture, and eventually this endeavor evolved into the first Geological Survey of England, with De la Beche as director. However, De la Beche was not content

“merely” to geologically map his country. He lobbied for the establishment of facilities and organizations dedicated to the growing professionalization and popularization of geology. The Museum of Practical Geology, the School of Mines, and the Mining Records Office were founded largely through his efforts. All of these organizations included educational pursuits in their purposes: De la Beche arranged museum specimens to facilitate education, promoted lectures for the lower socioeconomic classes as well as those in managerial positions, and organized mining data to aid and educate those involved in future mining activities. Although he participated in the elite geological circles inhabited by the privileged classes of gentlemen scientists, he advocated educational activities across social boundaries. His interactions with Mary Anning also indicate that De la Beche was willing to move beyond the gender biases of his time. He effectively straddled the elite circle of geologists, as well as the class of the emerging professionals. De la Beche eventually served as president of the Geologist Society of London, and was knighted for his service to his country.

Although many biographies have been written about the early geologists in the age of focus, De la Beche has never been the subject of an in-depth biography. James Hutton, Charles Lyell, and even William Buckland have been preserved for posterity, but Henry T. De la Beche remains a forgotten geological contributor in most geology classrooms. Perhaps the type of products he created is the underlying cause for his omission as an outstanding figure in geology: As a geological surveyor, De la Beche created geological maps. These objects were utilitarian in disposition, and the nature of our historical remembrances does not tend to elevate the practical over the theoretical. While most geology texts acknowledge Hutton and Lyell as important figures in the emerging field of modern geology, the citations rest on the selected segments of the

theories proposed by the geologists. While a person may be highly respected by his colleagues for his or her production of practical items, in historical references such a person is often reduced to a whisper.

Although James Hutton and Charles Lyell are acknowledged as important geologists today, they moved against most of their contemporaries, who believed that theories could not be postulated with so little factual evidence. De la Beche, like most of his colleagues, acknowledged that geology was a young science. He thought that the participants' duties were to observe natural occurrences and collect facts. In actuality, De la Beche believed that most theoretical postulations had ignored the facts in their development, and rested on scant evidence.

Not only did Henry T. De la Beche underscore the importance of facts and a well-integrated knowledge base in supporting theories, he also advocated that science be a function of society. He integrated the scientific with the practical or technological, and exposed the influences of geology upon many other fields of study. Architecture, mining, engineering, and chemistry were all acknowledged as important to the field of geology, as well as being influenced in turn by geology.

During the age of focus, the visual aspects of geology were recognized and promoted. More and more graphics were incorporated into publications in order to illustrate the printed word. Several factors influenced this growth, not the least of which was the development of the extensive utilization of wood engravings as a means of illustrative reproduction. An emerging educated class in the 1830s, coupled with a popular cultural interest in the natural sciences, also increased the success of the general geological text. However, with few exceptions, geological graphics in the Golden Age of Geology never approached explicit mathematical representations. The subject matter of

the time did not appear to mandate true graphical representation; it was far easier to draw what was observed or inferred from nature, and utilize this information to demonstrate a fact or generality. Geological graphs, such as phase diagrams, would have to wait until the science was well established. Unfortunately, as pointed out by Henry T. De la Beche, there was more *generalization* in the field of geology, with theories postulated on the basis of only a few examples. *Abstraction* and mathematical representation in the geological sciences had not yet come of age.

### The Father of Visual Geology Education

Even though mathematical graphics were missing from the visual repertoire in geology texts, there were several important graphic additions and innovations inaugurated in the Golden Age of Geology. Henry T. De la Beche emerged, in this research investigation, as an important contributor to visual geological representation, and a promoter and catalyst for geology education. Many of the innovative illustrations uncovered in this inquiry were developed and successfully incorporated by De la Beche; yet, his importance in visual geology education has gone unacknowledged.

During the pilot study, several of Henry T. De la Beche's geology texts were uncovered, including *How to Observe Geology* (1835), *A Geological Manual* (1831), and *Researches in Theoretical Geology* (1834b). These texts were initially noted as having large graphic inclusion for their time, especially *How to Observe Geology*. When several translations of *A Geological Manual* and *Researches in Theoretical Geology* materialized, it became obvious that De la Beche had played a major role in authoring several important geology texts during the age of focus. However, a paradox existed: As a geologist, I had never before heard of Henry T. De la Beche, either as a graduate

student in geology, or as an instructor of general geology and earth science classes at the university level.

When Martin Rudwick's (1975) paper on De la Beche's caricature sketches was located, an entirely new genre of geological illustrations was exposed. The scientific caricatures are truly Tufteian visual confections, exhibiting layered information on social, cultural, historical, and scientific interactions during the emergence of modern geology. Although Rudwick's (1975) discussion centered on the unpublished caricature sketches in one of De la Beche's field notebooks, McCartney's (1977) brief investigation into De la Beche's geological career highlighted additional scientific caricatures drawn by De la Beche during the Golden Age of Geology. Other examples were revealed in the De la Beche archives at the National Museum of Wales and Roderick Muchison's geological scrapbook in the British Geological Survey library. Neville Haile, whom I met on the History of Geology Group field trip in Bath, had uncovered another De la Beche caricature in William Buckland's collection at Oxford University, which he forwarded to me electronically. During the Golden Age of Geology, several De la Beche scientific caricatures were printed and distributed; comments from recipients prove that they were influential. Furthermore, only a few scattered examples of caricatures drawn by artists other than De la Beche emerged in this study; no one besides De la Beche systematically utilized this graphic form in the age of focus. Although scientific caricatures have been eliminated as illustrations in modern geology texts, they possess great potential to improve geoscience education today.

The discovery of *Sections and Views* (1830e) in this research investigation provided additional support for De la Beche's genius in visual geological education. This beautifully illustrated book was designed for instruction: De la Beche wished to



accurately portray data from the field so that his contemporaries would have access to the facts. Facts, according to De la Beche, remained long after the current explanation had faded into oblivion. In an unusual illustration, De la Beche employed the effect of vertical exaggeration on sectional views. This graphic was constructed, not as a representational view of what was observed in nature, but as an educational tool: De la Beche wished to persuade his geological colleagues that sections should be drawn just as they appear in nature, without vertical exaggeration. This purpose of this graphic, therefore, was strictly for the purpose of educating his reader through visual instruction.

In *Sections and Views*, De la Beche asserted that science was advanced through collision of various theories. His recommendation to his colleagues that sectional views be “miniature representations of nature” would ensure that geological scenes, when properly depicted, would provide valuable information for other geological endeavors in the future; as accurate depictions of facts, they might promote or hinder future theoretical debates. In his proposals, De la Beche pioneered *colliding theory graphics*, whose factual value would be retained for future generations and future theoretical considerations, regardless of the fate of the current theoretical flavor.

Besides the scientific caricatures and colliding theory graphics, Henry T. De la Beche introduced several important genres of visual explanation. The first use of a small multiple uncovered in this research study was De la Beche’s presentation of sections in *Sections and Views*. Although this is an extremely efficient format in which to present geological information, De la Beche’s employment was the only discovered small multiple application. The small multiple is also currently underutilized in modern geological illustrations, and offers potential in the classroom.

Henry T. De la Beche additionally established the illustrative genre of ancient life reconstructions. *Duria antiquior* is acknowledged as the first published scene from deep time. The aquarium viewpoint of the illustration, twenty years before the advent of the Victorian aquarium craze, further confirms De la Beche's innovative visual nature. De la Beche also was the first geological author to incorporate small format scenes from deep time in his general texts: The third edition as well as the French translation of *A Geological Manual* offered three illustrative vignettes of ancient life for the reader. De la Beche's scenes from deep time are also important for yet another reason: In William Buckland's classroom at Oxford, *Duria antiquior* became the first innovative geologic teaching graphic.

De la Beche's texts indicated that he was an early user of general diagrammatic representations. The general diagrams, in opposition to illustrations that specifically record and infer single scenes or objects from nature, are more characteristic of educational graphics: They teach general principles or occurrences, as an alternative to the imaging of separate facts. No clear pioneer of general diagrams was detected in this research study; it is possible that general representations evolved independently in many different texts. However, the fact remains that De la Beche incorporated general diagrams in his texts during the Golden Age of Geology, and he was one of the first geology book authors to do so successfully. Many of his general diagrams still represent accurate information, and can be successfully utilized in the classroom today.

The quantitative analysis of graphic density revealed that De la Beche generally did include more illustrations per total page count than his geological contemporaries. Visual representation was important to him: As a gifted artist, he was able to draw his own illustrations for his texts. De la Beche's visual nature and his perceived importance

of graphic representation are further reflected in his life through his diaries, field notebooks, and letters.

Although there were other geologists who were making significant contributions via illustrated texts, their styles and purposes differed from those of Henry T. De la Beche's. Lyell's three volumes of *Principles of Geology* were not as visual as De la Beche texts published at the same time, and when Lyell recast his theoretical proposals into a more generalized text in 1838, De la Beche had already established the highly illustrated general text three years earlier. Lyell's intention was also to present a theoretical view, not to make facts available or to educate a general reader.

Gideon Mantell also authored several illustrated texts in the age of focus. However, the Mantell texts uncovered in this study discussed specific geographic locations instead of general geological concerns. Although Mantell did eventually author general geology texts, those were published after the Golden Age of Geology.

In addition to introducing several important genres of visual explanation, De la Beche also launched modern geology education with the establishment of the Museum of Practical Geology, the School of Mines, and the Mining Record Office. No other geologist was as actively involved in promoting education for the general population.

Therefore, many factors combine to establish that Henry T. De la Beche was extremely influential as a geologist and a geology educator during the age of focus. De la Beche can claim the highest graphic density in texts published in the Golden Age of Geology. He introduced important genres of visual representation, including the caricature, scenes from deep time, and small multiple. He was also one of the pioneering users of the general diagram in geology texts. De la Beche advocated geology education; he was largely responsible for the founding of several institutions whose purpose

included educational activities. For De la Beche, education should transcend social boundaries; he was an early advocate for instruction of lower classes as well as the socially elite. As a geologist willing to move beyond the social and gender restrictions of his day, he interacted and acknowledged Mary Anning; he was also an early advocate for the safety of the laborers toiling in mines.

An overwhelming amount of evidence was gradually accumulated in this research investigation that proved Henry T. De la Beche was an outstanding geologist and geology educator during the Golden Age of Geology. Although he has not been previously acknowledged as the first visual geology educator, his use of small multiples, caricatures, scenes from deep time, and general educational diagrams illustrate that De la Beche introduced innovative graphic explanations and promoted geology education more than any other person during the emergence of geology as a modern science. Although his historical importance and graphic innovations have been virtually forgotten and ignored, it appears that Henry T. De la Beche should now be acknowledged as the Father of Visual Geology Education.

### De la Beche and Geoscience Education

The geosciences are very visual in nature, as evidenced by the number of illustrations in modern geology texts, as well as the number of graphics presented in geology lectures and seminars. However, this visual nature has evolved through the years: James Hutton first proposed his encompassing theoretical views with only two plates of illustrations. By the end of the Golden Age of Geology, the illustrative power of graphics had been realized, and with economic reproduction of illustrations available, many authors inserted numerous illustrations into their published texts.

Research supports the importance of graphic inclusion in texts. Levie and Lentz (1982) reported that effective use of illustrations in texts facilitated learning. Graphics are also an important tool in classroom presentation; our modern students have been constantly bombarded with visual information through television and video games, and are comfortable with intense visual stimuli (Gioia & Brass, 1985 – 86). In most educational situations, illustrations are recognized as an important aspect in the presentation of knowledge. The British Library, for example, exhibits rare manuscripts in the John Ritblat Gallery; the majority of the rare treasures presented have been turned to pages with beautiful illustrations.

The search for new and innovative illustrative presentations for geoscience education continues. Collins (2002) reported that new animated video documentaries are now produced to educate viewers about New York geology. These videos promote geotourism for the region, and will be available at various New York museums and visitor centers. Unfortunately, as the exploration continued for new and effective illustrative methods to satisfy the visual nature of geology, many of the older innovative illustrations have been forgotten.

Based on extensive evidence gathered in the United States and the United Kingdom, De la Beche's scientific caricatures, scenes from deep time, small multiples, and diagrammatic representations have emerged as visual, diagram-based learning approaches applicable in the modern geoscience classroom. While diagrams and small multiples provide efficient methods to communicate geological information, the scientific caricatures and scenes from deep time also lend themselves to deeper, less-superficial understanding of key geoscience ideas. It is proposed that caricatures can be introduced into the geology classroom to facilitate student appreciation of the historical context of

the development of theories, as well as to promote knowledge restructuring and conceptual framework expansion. In addition, they may offer students the visual opportunity to extract and critically evaluate socially embedded scientific knowledge and value claims.

The inclusion of Henry T. De la Beche's history also offers benefits in addition to his innovative illustrations. Students can gain insight into the social, political, and cultural interactions that helped to mold the emerging science of geology. Students have the potential to gain a deeper understanding of a scientific method, as well as characteristics of a scientific mind. De la Beche's history illustrates the articulation of geology with other fields of study, and effectively demonstrates the evolving theories and mindsets that characterize the nature of geology. Henry T. De la Beche can also provide an historical role model for students; many of his actions transcended the social and gender barriers of his time. De la Beche utilized his government position to further geological endeavors for all classes of people. He considered the contributions of the working classes, as well as the socially elite. He promoted education for everyone, regardless of social class.

Many science classrooms could benefit from the addition of scientific heroes, especially when the heroes have made gains in educational and social endeavors in addition to their scientific accomplishments. As the Father of Visual Geology Education, Henry T. De la Beche provides an ideal example of an historical figure who should be made available to geoscience students.

### Implications for Future Research

This research investigation uncovered historical influences on the emerging field of modern geology and its increasing dependence on graphics, as well as qualitative and

quantitative trends in the graphic forms of Henry T. De la Beche. Graphic analysis using Edward R. Tufte's theory of graphic design revealed the nature and progression of early geological graphics, and determined strengths and weaknesses within illustrative forms. These findings were utilized in determining the role of Henry T. De la Beche and his geology graphics in shaping early geological thought, in addition to the implications for the modern geology classroom. However, this research investigation has also indicated potential areas for further research, including possible historical exploration, statistical analyses, and especially research in the modern geoscience classroom environment.

Although attempts were made to locate all important geology texts published between 1788 and 1840, Britons or Americans authored most of the texts uncovered and analyzed. This is probably due to the manner in which the American and British people reconstruct history, elevating their own contributors above foreigners. However, it was ascertained that continental European countries were far ahead of England in the professionalization of geology in the age of focus. Although texts by foreign authors were mentioned in some history of geology sources, the number does not appear to reflect the stage of geological research in continental Europe. The foreign geology texts should be more thoroughly investigated. This will probably be an involved study, since translation of texts will be required; research trips to foreign countries will probably also be mandated in order to acquire some of the perceived lesser foreign texts.

Hypothesis testing around correlation coefficients for publication years and graphic density, as well as for publication years and total number of included illustrations, was done with sufficient sample sizes. However, because of the sampling techniques, the selection of texts for inclusion in the study was not as random as possible. The data, therefore, might not be as ideally representative of the population as would be

preferred. A future investigation might involve correlation analysis with a strictly random sample, which would hopefully include more texts from foreign geology authors.

Further detailed studies, similar to the analyses conducted on De la Beche's graphic forms, might also be conducted for the types of illustrations included in texts authored by geologists other than Henry T. De la Beche. Different analyses might be conducted that would mathematically reveal the amount of chartjunk contained in a graphic; this could be done by determination of unaltered white space within an illustration. The total amount of data ink and graphic content area in texts could be examined also, instead of the number of graphics, and the resultant graphic density.

However, the most important future studies indicated by this research investigation are those classroom studies that will ascertain the effectiveness of De la Beche's graphic forms, and the inclusion of the history of geology in the geoscience classroom. Possibilities for these future research studies include, but are not limited to, the determination of the usefulness of De la Beche's scientific caricatures in introductory geoscience classrooms in learning the important geological construct of uniformitarianism, and the debates that led to its acceptance. De la Beche's scientific caricatures and historical interactions during the Devonian conflict might also be incorporated into a classroom. These should be subsequently investigated to ascertain whether such inclusion provides students with a more complete understanding of the nature of the scientific enterprise, and an understanding of the artificiality of the construct of geological time. Incorporation of the history of geology through Henry T. De la Beche might be investigated as to its effectiveness in creating meaningful learning and knowledge restructuring in the classroom. Whether or not students have glimpsed and embraced the scientific mindset can be determined through their own planning of



individual research investigations. Tools that can be employed to measure conceptual change in the classroom include concept maps as well as descriptive essays. Student-created products – such as scientific caricatures, scenes from deep time, and small multiples – are also valuable assessment methods that can effectively capture the restructuring of knowledge.

## Conclusion

Research into the use of illustrations during the early formative years of geology revealed several trends. Initial graphics were proxy images, with low data density and heavy chartjunk. As geology progressed and became a more established science, early textbooks emerged. These early texts introduced new types of graphics, including labeled proxy images and inferred depictions, especially of sectional views. Addition of color to some early geological texts was skillfully done, and in some cases, illustrations were created that resembled works of art more than graphic explanations.

The 1820s witnessed publication of geological texts with elaborate graphics. The grandly illustrated texts appeared to be targeted toward the elite circles of scientists. Directional information was layered onto some graphics for the first time. In the 1830s, however, a growing educated professional class emerged in England, and a popular market for general geology texts began. Texts published in the 1830s tended to be visual and included many illustrations; however, the grand use of color and illustration was missing in most of the 1830s texts. Small multiples and scenes from deep time were new additions to the graphic arsenal, and in the 1830s the scientific caricature also became a mode of visual communication, although it was never published in texts. Very few of the graphics showed causal relationships, however. Even at the end of the Golden Age of

Geology, most illustrations were non-mathematical, and indicate that geology was still in a pre-graph era.

Numbers of illustrations included in published texts also changed throughout the Golden Age of Geology. In the earliest publications, illustrations were sparingly used, if they were present at all. The popular use of wood engravings in the later texts allowed easier and economical reproduction of graphic images, and texts published late in the age of focus tended to have more illustrations than texts published at the beginning.

Hypothesis testing around a correlation coefficient did show significance at the 99% confidence level for a relationship between the publication year and the graphic density of texts, as well as for a relationship between the publication year and the total number of illustrations included in texts.

The use of wood engravings as a method for illustration reproduction apparently had a large effect on the number of included illustrations. Geology texts were also influenced by the popular cultural interest in natural history, and the development of a professional class. Religious influences were apparent in some texts. Social and gender barriers effectively determined at what level a person could participate in the new science; most of the general texts were written by those geologists accepted in the elite geological societies.

In this investigation, Henry T. De la Beche, through his illustrations and promotion of geology education, emerged as the Father of Visual Geology Education. A large amount of evidence supports this claim: De la Beche was the first to utilize the small multiple graphic format, the first to draw a scene from deep time, the first to incorporate small vignettes from deep time in a general text, and the only geologist who regularly drew scientific caricatures to represent some of the theoretical debates of the

day. In addition, Henry T. De la Beche was one of the first geologists who utilized general diagrammatic representations, as opposed to illustrations representing a single scene or object. His educational purposes are evidenced not only in his texts and illustrations; the Museum of Practical Geology, the School of Mines, and the Mining Record Office were established largely through his efforts. Each institution incorporated some type of educational purpose or activity. De la Beche, as the first Director General of the newly formed Geological Survey, used his position well: He furthered the professionalization of the science of geology in Britain, and taught his techniques and ideas to many who worked under him in the Survey. Some of these men would later spread his influence worldwide. De la Beche also was willing to move beyond the social and gender constraints of his day. His accomplishments make him a suitable character for a scientific hero in modern geoscience classrooms.

The declaration of De la Beche as the Father of Visual Geology Education has implications, not only in the way we view the history of geology, but also for geoscience education today. Correcting the forgotten status of De la Beche elevates a historical producer of utilitarian objects, as opposed to our selective remembrances and acknowledgement of those who postulated grand theoretical views. The incorporation of De la Beche's history has the power to enliven the curriculum, provide students with a glimpse of the scientific mindset, avoid final form science, and uncover the actual nature of the scientific enterprise in the classroom.

The innovative graphic forms developed by De la Beche also have potential to enrich the geoscience classroom. The small multiples, general diagrammatic representations, scenes from deep time, and scientific caricatures still have relevance in the geology classroom today. Although we now acknowledge that geology is a visual

science, current trends appear to promote the invention of new graphic tools and visualization techniques. However, the De la Beche graphics, especially the scientific caricatures, have the ability to show students the cultural, political, and social interactions involved in the modification of theories during the emergence of geology as a science. Progress is not always an erasure of the past; it can also be the rediscovery and reappropriation of good ideas that were lost over time. The historical accounts and the graphic innovations of Henry T. De la Beche, the Father of Visual Geology Education, appear to have the power to transform our geoscience classrooms and promote meaningful learning among our students.

## References

- Allen, D. E. (1976). *The naturalist in Britain: A social history*. London: Allen Lane.
- Andersen, H. (2000). Learning by ostension: Thomas Kuhn on science education. *Science and Education*, 9, 91-106.
- Ault, C. R., Jr. (1994) Research on problem solving: Earth science. In D. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 269-283). New York: Macmillian Publishing Company.
- Aubuisson de Voisins, J. F. (1819). *Traité de géognosie*. Strasbourg: F. G. Levrault.
- Aubuisson de Voisins, J. F. (1828-1835). *Traité de géognosie* (nouvelle edition). Paris: Levrault.
- Ausubel, D. P. (1963). *The psychology of meaningful verbal learning*. New York: Grune and Stratton.
- Ausubel, D. P. (1968). *Educational psychology: A cognitive view*. New York: Holt, Rinehart and Winston.
- Aydelotte, W. O. (1963). Notes on the problem of historical generalization. In L. Gottschalk (Ed.), *Generalization in the writing of history* (pp. 145-177). Chicago: University of Chicago Press.
- Bakewell, R. (1813). *An introduction to geology: Illustrative of the general structure of the earth : comprising the elements of the science, and an outline of the geology and mineral geography of England*. London: J. Harding.
- Bakewell, R. (1829). *An introduction to geology: Comprising the elements of the science in its present advanced state, and all the recent discoveries; with an outline of the geology of England and Wales* (3rd ed.). New Haven, CT: Hezekiah Howe.
- Bakewell, R. (1839). *An introduction to geology, intended to convey a practical knowledge of the science, and comprising the most important recent discoveries; with explanations of the facts and phenomena which serve to confirm or invalidate various geological theories* (3rd ed. from the 5th London ed.) New Haven, CT: B & W. Noyes.
- Bailey, E. B. (1952). *Geological Survey of Great Britain*. London: Thomas Murby & Co.
- Bailey, E. B. (1967). *James Hutton – The founder of modern geology*. London: Elsevier Publishing Co. Ltd.

- Barry, C., De la Beche, H. T., Smith, W., & Smith, C. H. (1839). Report with reference to the selection of stone for building the new Houses of Parliament. *Parliamentary Papers for 1839*, 30, 1-36.
- Barstow, D., & Geary, E. (2001). A blueprint for earth science education. *Geotimes*, 46, 21-23.
- Beniger, J. R., & Robyn, D. L. (1978). Quantitative graphics in statistics: A brief history. *The American Statistician*, 32, 1-11.
- Best, J. W., & Kahn, J. V. (1993). *Research in education*. Boston: Allyn and Bacon.
- Blundell, D. J., & Scott, A. C. (1998). Introduction. In D. J. Blundell & A. D. Scott (Eds.), *Lyell: The past is the key to the present* (pp. vi-vii). London: Geological Society.
- Boase, H. S. (1834). *A treatise on primary geology, being an examination, both practical and theoretical, of the older formations*. London: Longman, Rees Orme, Brown, Green & Longman.
- Bogdan, R. C., & Biklen, S. J. (1998). *Qualitative research for education: An introduction to theory and methods* (3rd ed.). Boston: Allyn & Bacon.
- Boubée, N. (1833). *Géologie élémentaire, a la portée de tout le monde, appliquée a l'agriculture et a l'industrie*. Paris: Bureau du Nouveau Bulletin d'Histoire Naturelle.
- Breislak, S. (1811). *Introduzione alla geologia*. Milano: Stamperia Reale.
- Breislak, S. (1818-1822). [*Institutions géologiques.*] *Traité sur la structure extérieure du globe, ou Institutions géologiques*. Milano: Stamperia Reale.
- Brewer, R. C., Bolton, J. C., & Driese, S. G. (1990). A new classification of sandstone. *Journal of Geological Education*, 38, 343-347.
- Buckland, W. (1816). Letter. Archived document (NMW 144). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- Buckland, W. (1824). *Reliquiae diluvinae, or observation on the organic remains contained in caves, fissures, and diluvial gravel, and on other geological phenomena, attesting the action of an universal deluge* (2nd ed.). London: John Murray.
- Buckland, W. (1829). Letter to Henry T. De la Beche. Archived document (NMW 177). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- Buckland, W. (1830). Letter to Henry T. De la Beche. Archived document (NMW 179). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.

- Buckland, W. (1831a). Letter to Henry T. De la Beche. Archived document (NMW 180). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- Buckland, W. (1831b). Letter to Henry T. De la Beche. Archived document (NMW 182). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- Buckland, W. (1831c). Letter to Henry T. De la Beche. Archived document (NMW 183). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- Buckland, W., & De la Beche, H. T. (1835). On the geology of the neighbourhood of Weymouth and the adjacent parts of the coast of Dorset. *Transactions of the Geological Society of London, Second Series*, 4, 1-46.
- Burek, C. V. (2001). Where are the women in geology? *Geology Today*, 17, 110-113.
- Bybee, R. W., & Pratt, H. A. (1996). National standards: Challenges for earth science education. *Geotimes*, 41, 16-19.
- Carr, E., & Ogle, D. (1987). K-W-L Plus: A strategy for comprehension and summarization. *Journal of Reading*, 30, 626-631.
- Chenevix, R. (1811). *Observations on mineralogical systems*. London: J. Johnson & Co.
- Chi, M. (1997). Quantifying qualitative analyses of verbal data: A practical guide. *The Journal of the Learning Sciences*, 6, 271-315.
- Chubb, L. J. (1958). Sir Henry Thomas De la Beche. *Geonotes*, 1, 1-30.
- Clair, C. (1976). *A history of European printing*. London: Academic Press.
- Cleaveland, P. (1816). *An elementary treatise on mineralogy and geology being an introduction to the study of these sciences and designed for the use of pupils, - for persons, attending lectures on these subjects, and as a companion for travellers in the United States of America*. Cambridge, MA: Hilliard & Metcalf.
- Clinton, D. (1815). *An introductory discourse, delivered before the Literary and Philosophical Society of New-York, on the fourth of May, 1814*. New York: D. Longworth.
- Collins, G. (2002, July 25). Making the rocks speak. *New York Times*. Retrieved July 25, 2002 from <http://www.nytimes.com>
- Conant, J. B. (1947). *On understanding science: An historical approach*. New Haven, CT: Yale University Press.
- Condie, K. C., & Sloan, R. E. (1997). *Origin and evolution of earth*. Upper Saddle River, NJ: Prentice Hall.

- Conybeare, W. D. (1821a). Letter to Henry T. De la Beche. Archived document (NMW 297). Retrieved July 10, 2002 from Cardiff: National Museum of Wales.
- Conybeare, W. D. (1821b). Letter to Henry T. De la Beche. Archived document (NMW 299). Retrieved July 10, 2002 from Cardiff: National Museum of Wales.
- Conybeare, W. D. (1824). Letter to Henry T. De la Beche. Archived document (NMW 302). Retrieved July 10, 2002 from Cardiff: National Museum of Wales.
- Conybeare, W. D., & De la Beche, H. T. (1823). *Map of 24 miles around the city of Bath by C. Harcourt Masters, coloured geologically by Rev. W. D. Conybeare and H. T. De la Beche*. Bath, England.
- Conybeare, W. D., & Phillips, W. (1822). *Outlines of the geology of England and Wales, with an introductory compendium of the general principles of that science, and comparative view of the structure of foreign countries*. London: William Phillips.
- Conybeare, W. D., & Phillips, W. (1978). *Outlines of the geology of England and Wales, with an introductory compendium of the general principles of that science, and comparative view of the structure of foreign countries*. New York: Arno Press. (Original work published 1822)
- Craig, G. Y. (1978). *James Hutton's Theory of the Earth: The lost drawings*. Ipswich, Great Britain: Scottish Academic Press Ltd.
- Creswell, J. W. (1994). *Research design: Qualitative and quantitative approaches*. Thousand Oaks, CA: Sage Publications.
- Creswell, J. W. (1998). *Qualitative inquiry and research design: Choosing among five traditions*. Thousand Oaks, CA: Sage Publications.
- Cuvier, G. (1818). *Essay on the theory of the earth*. New York: Kirk and Mercein.
- Cuvier, G. (1822). *Recherches sur les ossemens fossiles, où l'on rétablit les caractères de plusieurs animaux dont les révolutions du globe ont détruit les espèces* (Vol. II, part 2, 3rd ed.). Paris: Dufour & E. D'ocagne.
- Cuvier, G. (1825a). *Recherches sur les ossemens fossiles, les caractères de plusieurs animaux dont les révolutions du globe ont détruit les espèces* (3rd ed.). Paris: Chez G. Dufour et E. D'ocagne.
- Cuvier, G. (1825b). *Recherches sur les ossemens fossiles, où l'on rétablit les caractères de plusieurs animaux dont les révolutions du globe ont détruit les espèces* (Vol. I, 3rd ed.). Paris: Chez. G. Dufour & E. D'ocagne.
- Cuvier, G. (1831). *A discourse on the revolutions of the surface of the globe, and the changes thereby produced in the animal kingdom* (trans.) Philadelphia: Carey & Lea.



- Cuvier, G. (1992). *Recherches sur les ossements fossils de quadrupèdes*. Paris: Flammarion. (Original work published 1812)
- Cuvier, G., & Brongniart, A. (1969). *Description géologique des environs de Paris*. Brussels: Culture et Civilisation. (Original work published 1822)
- Dana, J., & Dana, S. (1818). *Outlines of the mineralogy and geology of Boston and its vicinity with a geological map*. Boston: Cummings and Billiard.
- De la Beche, H. T. (n.d.-a). Geological sketch map of Gulf of Spezia. Archived document (NMW 437). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (n.d.-b) Leaf rubbings and pencil sketch. Archived document (NMW 439). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (n.d.-c). Map of Devon. Unarchived document (AM11125 Serial No.) Retrieved July 16, 2002 from Keyworth, England: British Geological Survey.
- De la Beche, H. T. (n.d.-d). Painting of forest at Stolford. Archived document (LDGSL 400/59). Retrieved July 4, 2002 from London: Geological Society.
- De la Beche, H. T. (n.d.-e). Sketch and plans of a horse engine. Archived document (NMW 438). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (n.d.-f). Sketch of landscape. Archived document (NMW 440.1-2). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (n.d.-g). Sketch of Snowdon Peak. Archived document (NMW 436). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (n.d.-h). Sketch of White Chapel Pinney (NMW New Archives 00.16G.D1). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (n.d.-i). Sketchbook. Archived document (NMW 433). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (n.d.-j). Trilobite lithograph. Archived document (NMW 431.1-3). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1815a). Painting of Zennor Cliff. Archived document (LDGSL 400/61). Retrieved July 4, 2002 from London: Geological Society.
- De la Beche, H. T. (1815b). Personal diary. Archived document (GSM 1/831). Retrieved July 16, 2002 from Keyworth, England: British Geological Survey.
- De la Beche, H. T. (1816). Personal diary. Archived document (GSM 1/830). Retrieved July 16, 2002 from Keyworth, England: British Geological Survey.

- De la Beche, H. T. (1817a). Ichthyosaur paintings. Archived document (LDGSL 640). Retrieved July 4, 2002 from London: Geological Society.
- De la Beche, H. T. (1817b). Ichthyosaur paintings. Archived documents. (LDGSL 641). Retrieved July 4, 2002 from London: Geological Society.
- De la Beche, H. T. (1818). Pocket journal. Archived document (NMW 341). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1819a). On the depth and temperature, sur la profondeur et la temperature du lac de Genève. Lettre adressee au Prof. Pictet par Mr H. T. De la Beche. *Bibliothèque Universelle*, 12, 118-126.
- De la Beche, H. T. (1819b). Pocket journal. Archived document (NMW 342). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1819c). Pocket journal. Archived document (NMW 343). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1819d). Pocket journal. Archived document (NMW 344). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1819e). Pocket journal. Archived document (NMW 345). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1819f). Pocket journal. Archived document (NMW 346). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1820a) Field notebook. Archived document (NMW 348). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1820b). On the depth and temperature of the Lake of Geneva. Communicated by Professor Pictet. With a map. *Edinburgh Philosophical Journal*, 2, 106-110.
- De la Beche, H. T. (1820c). Pocket journal. Archived document (NMW 347). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1820d). Pocket journal. Archived document (NMW 349). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1820e) Print of a crocodile. Archived document (LDGSL 635). Retrieved July 4, 2002 from London: Geological Society.
- De la Beche, H. T. (circa 1821). Ichthyosaurus sketches. Archived document (IGS1/815). Retrieved July 16, 2002 from Keyworth, England: British Geological Survey.

- De la Beche, H. T. (1821). Pocket journal. Archived document (NMW 350). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1822a). On the geology of the south coast of England, from Bridport Harbour, Dorset, to Babbacombe Bay, Devon. *Transactions of the Geological Society of London, Second Series, 1*, 40-47.
- De la Beche, H. T. (1822b). On the geology of the coast of France, and of the inland country adjoining; from Fécamp, Department de la Seine Inferieure, to St Vaast, Department de la Manche. *Transactions of the Geological Society of London, Second Series, 1*, 73-89.
- De la Beche, H. T. (1823a). Extended Jamaican journal. Archived document (NMW 353). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1823b). Pocket journal. Archived document (NMW 352). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1824a). *A selection of the geological memoirs contained in the Annales des Mines, together with a synoptical table of equivalent formations, and M. Brognairt's table of the classification of mixed rocks translated, with notes.* London: William Phillips.
- De la Beche, H. T. (1824b). Letter to W. D. Conybeare. Archived document (NMW 355). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1824c). Letter to W. D. Conybeare. Archived document (NMW 356). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1824d). Letter to W. D. Conybeare. Archived document (NMW 357). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1825a). Catalogue of the birds, and of terrestrial and fluviatile molluscae, found in the vicinity of Geneva. *Zoological Journal, 1*, 89-93.
- De la Beche, H. T. (1825b). Notes on the diluvium of Jamaica. *Annals of Philosophy, New Series, 10*, 54-58.
- De la Beche, H. T. (1825c) *Notes on the present conditions of the Negroes in Jamaica.* London: T. Cadell.
- De la Beche, H. T. (1825d). Paintings of belemnites. Archived document (LDGSL 256). Retrieved July 4, 2002 from London: Geological Society.
- De la Beche, H. T. (1826a). On the Lias of the coast in the vicinity of Lyme Regis, Dorset. *Transactions of the Geological Society of London, Second Series, 2*, 21-30.

- De la Beche, H. T. (1826b). On the geology of southern Pembrokeshire. *Transactions of the Geological Society of London, Second Series, 2*, 1-20.
- De la Beche, H. T. (1826c). On the chalk and sands beneath it (usually termed green-sand) in the vicinity of Lyme Regis, Dorset and Beer, Devon. *Transactions of the Geological Society of London, Second Series, 2*, 109-118.
- De la Beche, H. T. (1827a). Lithograph view of Jamaica. Archived document (LDGSL 94). Retrieved July 4, 2002 from London: Geological Society.
- De la Beche, H. T. (1827b). Remarks on the geology of Jamaica. *Transactions of the Geological Society of London, Second Series, 2*, 143-194.
- De la Beche, H. T. (1827c). *A tabular and proportional view of the superior, supermedial and medial rocks; (Tertiary and Secondary rocks.)* London: William Phillips.
- De la Beche, H. T. (1828). Diary. Archived document (NMW 363). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (circa 1829). A coprolitic vision. Archived document (GSM 1/558). Retrieved July 16, 2002 from Keyworth, England: British Geological Survey.
- De la Beche, H. T. (1829a). Letter to William Buckland. Archived document (NMW 364). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1829b). On the geology of Tor and Babbacombe Bays, Devon. *Transactions of the Geological Society of London, Second Series, 3*, 161-170.
- De la Beche, H. T. (1829c). On the geology of the environs of Nice and the coast thence to Vintimiglia. *Transactions of the Geological Society of London, Second Series, 3*, 171-185.
- De la Beche, H. T. (1829d). Notice on the excavation of valleys. *Philosophical Magazine and Annals of Philosophy, New Series, 6*, 241-248.
- De la Beche, H. T. (1829e). Print of a trilobite. Archived document (LDGSL 587). Retrieved July 4, 2002 from London: Geological Society.
- De la Beche, H. T. (circa 1830a). *Duria antiquior* original watercolor. Archived document (NMW 368). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (circa 1830b). Field notebook. Archived document (GSM 1/123). Retrieved July 16, 2002 from Keyworth, England: British Geological Survey.
- De la Beche, H. T. (circa 1830c). Field notebook. Archived document (GSM 1/123ii). Retrieved July 16, 2002 from Keyworth, England: British Geological Survey.

- De la Beche, H. T. (circa 1830-1833). Cause and effect caricature. Archived document (Misc. mss./12). Retrieved July 20, 2002 from personal electronic communication, Neville Haile. Original held in Oxford: Buckland papers, Oxford University Museum of Natural History.
- De la Beche, H. T. (1830a). Awful changes. Archived documents. (NMW 367.1-25). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1830b). *Geological notes*. London: Treuttel and Würtz.
- De la Beche, H. T. (1830c). Map and sections of Weymouth. Archived document (LDGSL 98). Retrieved July 4, 2002 from London: Geological Society.
- De la Beche, H. T. (1830d). Painting of a Geological Society meeting. Archived document (LDGSL 312). Retrieved July 4, 2002 from London: Geological Society.
- De la Beche, H. T. (1830e). *Sections and views, illustrative of geological phænomena*. London: Truettel & Würtz.
- De la Beche, H. T. (1831). *A geological manual*. London: Treuttel and Würtz.
- De la Beche, H. T. (1832a). Etching of an island. Archived document (NMW 371.1-2). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1832b). *Geological manual*. Philadelphia: Carey & Lea.
- De la Beche, H. T. (1832c). *Handbuch der geognosie*. Berlin: Verlag von Duncker und Humblot.
- De la Beche, H. T. (1832d). Interleaved copy of *Geological Manual*. Archived document (IGS 1/566). Retrieved July 15, 2002 from Keyworth, England: British Geological Survey.
- De la Beche, H. T. (1832e). Notes on the economical advantages of geological maps. Archived document (NMW 372). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1833a). *A geological manual* (3rd ed.). London: Charles Knight.
- De la Beche, H. T. (1833b). *Manuel géologique* (2nd edition). Paris: Langlois et Leclercq.
- De la Beche, H. T. (1834a). Print of an ichthyosaur. Archived document (LDGSL 642). Retrieved July 4, 2002 from London: Geological Society.
- De la Beche, H. T. (1834b). *Researches in theoretical geology*. London: Charles Knight.

- De la Beche, H. T. (1835). *How to observe geology*. London: Charles Knight.
- De la Beche, H. T. (1836). *Anteilung aum wissenschaftl. Beobachten. Geologie*. Berlin: Beit und Comp.
- De la Beche, H. T. (1837a). *Duria antiquior* colored lithograph. Archived document (GSM 1/558). Retrieved July 15, 2002 from Keyworth, England: British Geological Survey.
- De la Beche, H. T. (1837b). *Duria antiquior* lithograph. Archived document (LDGSL 646). Retrieved July 4, 2002 from London: Geological Society.
- De la Beche, H. T. (1837c). *Manuel géologique* (2nd ed.). Brussels: Meline, Cans et Comagnie.
- De la Beche, H. T. (1837d). Mining Chronicle. Archived document (NMW 377). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1837e). *Researches in theoretical geology*. New York: F. J. Huntington & Co.
- De la Beche, H. T. (1838a). *L'Art d'observer en géologie*. Paris: Levrault.
- De la Beche, H. T. (1838b). *Recherches sur la partie théorique de la géologie*. Paris: Chez F. G. Levrault.
- De la Beche, H. T. (1838c). State of the Survey of England in January 1838. Archived document (NMW 384). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1839a). Ink sketch. Archived document (NMW 434). Retrieved July 9, 2002 in Cardiff: National Museum of Wales.
- De la Beche, H. T. (1839b). *Report on the geology of Cornwall, Devon, and West Somerset*. London: Longman, Orme, Brown, Green, and Longmans.
- De la Beche, H. T. (1841a). Irregularities of Sol. Archived document (NMW 395). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1841b). Letter to William Buckland. Archived document (NMW 396). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1844). On estuaries and their tides. *Philosophical Magazine*, 24, 485-491.

- De la Beche, H. T. (1845a). Instructions for the local directors of the Geological Surveys of Great Britain and Ireland. Archived document (GSM 1/4 Entry Book of In-And-Out Letters 1845-1846). Retrieved July 16, 2002 from Keyworth, England: British Geological Survey.
- De la Beche, H. T. (1845b). *Report on the state of Bristol, Bath, Frome, Swansea, Merthyr Tydfil, and Brecon, England*. London: W. Clowes & Sons.
- De la Beche, H. T. (1849). Letter to Sir George Grey. Archived document (GSM 1/5, p. 109-116). Retrieved July 15, 2002 from Keyworth, England: British Geological Survey.
- De la Beche, H. T. (1850). Letter to Lord Seymour. Archived document (GSM 1/6, p. 8-11). Retrieved July 15, 2002 from Keyworth, England: British Geological Survey.
- De la Beche, H. T. (1851a). *The geological observer*. London: Longman, Brown, Green, & Longmans.
- De la Beche, H. T. (1851c). Sketches. Archived document (NMW 435.1-2). Retrieved July 8, 2002 from Cardiff: National Museum of Wales.
- De la Beche, H. T. (1852). Inaugural discourse, delivered at the opening of the School of Mines and of Science Applied to the Arts, 6 Nov 1851. *Records of the School of Mines and of Science Applied to the Arts, 1*, 1-22.
- De la Beche, H. T., & Conybeare, W. D. (1821). Notice of the discovery of a new fossil animal, forming a link between the ichthyosaurus and crocodile; together with general remarks on the osteology of the ichthyosaurus. *Transactions of the Geological Society of London, first series, 5*, 559-594.
- De la Beche, H. T., & Playfair, L. (1847). Gases and explosions in collieries. *Journal of the Franklin Institute of the State of Pennsylvania, 13*, 347-353, 427-433.
- De la Beche, H. T., & Playfair, L. (1848). *First report on the coals suited to the steam navy*. London: William Clowes and Sons.
- De la Beche, H. T., & Playfair, L. (1849). *Second report on the coals suited to the steam navy*. London: William Clowes and Sons.
- De la Beche, H. T., & Playfair, L. (1851). *Third report on the coals suited to the steam navy*. London: William Clowes and Sons.
- De la Beche, H. T., & Reeks, T. (1876). *Catalogue of specimens in the Museum of Practical Geology, illustrative of the composition and manufacture of British pottery and porcelain, from the occupation of Britain by the Romans to the present time*. London: George E. Eyre and William Spottiswoode.

- De Luc, J. A. (1809). *An elementary treatise on geology: determining fundamental points in that science, and containing an examination of some modern geological systems, and particularly of the Huttonian theory of the earth* (H. De la Fite, Trans.). London: F. C. and J. Rivington.
- De Luc, J. A. (1831). *Letters on the physical history of the earth, addressed to Professor Blumenbach: Containing geological and historical proofs of the divine mission of Moses*. London: C. J. G. and F. Rivington.
- Denzin, N. K. (1978). The logic of naturalistic inquiry. In N. K. Denzin (Ed.), *Sociological methods: A sourcebook*. New York: McGraw-Hill.
- Devèze de Chabriol, J. S. (1827). *Essai géologique et minéralogique sur les environs d'Issoire*. Clermont-Ferrand: Thibaud-Landriot.
- Dunham, K. C. (1991). Foreward [relating to 175th anniversary of the Society and 150th anniversary of the publication of De la Beche's *Report on the geology of Cornwall, Devon, and West Somerset*]. *Transactions of the Royal Geological Society of Cornwall*, 21, 213-216.
- Duschl, R. (1985). Science education and philosophy of science: Twenty-five years of mutually exclusive development. *School Science and Mathematics*, 85, 541-555.
- Duschl, R. A. (1990). *Restructuring science education: The importance of theories and their development*. New York: Teachers College Press.
- Duschl, R. A. (1994). Research on the history and philosophy of science. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 443-465). New York: Macmillan Publishing Company.
- Eaton, A. (1818). *An index to the geology of the northern states with a transverse section from Catskill Mountains to the Atlantic*. Leicester: Hori Brown.
- Eaton, A. (1824). *A geological and agricultural survey of the district adjoining the Erie Canal in the state of New York*. Albany: Packard & Van Benthuyssen.
- Elie de Beaumont, J. B. (1832). Letter to Henry T. De la Beche. Archived document (NMW 495). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- Eves, R. L., & Davis, L. E. (1988). Is the rock cycle an outdated idea, or a unifying concept? *Journal of Geological Education*, 36, 108-110.
- Eyles, V. A. (1970). Introduction. In G. W. White (Ed.) *Contributions to modern Geology* (Vol. 5, pp. xi-xxiii). Darien, CT: Hafner Publishing Co.
- Eyles, V. A., & Eyles, J. M. (1955). Two geological centenaries: G. B. Greenough, F. R. S. (1778-1855) and Sir Henry De la Beche, F. R. S. (1796-1855). *Nature*, 175, 658-660.



- Finch, J. (1833). *Travels in the United States of America and Canada, containing some account of their scientific institutions, and a few notices of the geology and mineralogy of those countries*. London: Longman, Rees, Orme, Brown, Green, and Longman.
- Finley, M. I. (1963). Generalizations in ancient history. In L. Gottschalk (Ed.), *Generalization in the writing of history* (pp. 19-35). Chicago: University of Chicago Press.
- Flett, J. S. (1937). *The first hundred years of the Geological Survey of Great Britain*. London: Her Majesty's Stationery Office.
- Ford, B. (1993). *Images of science: A history of scientific illustration*. New York: Oxford University Press.
- Fuller, J. G. C. M. (2001, June). *Organic metamorphism in Pennsylvania: Henry Darwin Rogers and the origin of petroleum, 1863*. Paper presented at Oil City, PA.
- Fuller, J. G. C. M., & Torrens, J. S. (2002, July). *The industrial basis of stratigraphy: Events and places in the history of John Strachey and William Smith from 1719 to 1813*. Field trip guide for the History of Geology Group, Bath, England.
- Geikie, A. (1905). *The founders of geology* (2nd ed.). London: Macmillan and Co., Limited.
- Geikie, A. (1997). Preface. In A. Geikie (Ed.) *Theory of the earth with proofs and illustrations volume III* (pp. ix-xvi). London: Geological Society. (Original work published 1899)
- Gillispie, C. C. (1959). *Genesis and geology: A study in the relations of scientific thought, natural theology, and social opinion in Great Britain, 1790-1850*. New York: Harper & Brothers.
- Gioia, D. A., & Brass, D. J. (1985-86). Teaching the TV generation: The case for observational learning. *Organizational Behavior Teaching Review*, 10, 11-18.
- Girardin, J. P. L., & Lecoq, H. (1826). *Éléments de minéralogie appliquée aux sciences chimiques. Ouvrage basé sur la méthode de M. Berzelius contenant l'histoire naturelle et metallurgique des substances minerales, lers applications a la pharmacie, a la medecine et a l'Economie domestique*. Paris: Thomine.
- Glaser, B. G., & Strauss, A. L. (1967). *Discovery of grounded theory for qualitative research*. Chicago: Aldine.
- Globus, A., & Raible, E. (1994) Fourteen ways to say nothing with scientific visualization. *Computer*, 27, 86-89.

- Godley, R. C., & Wandersee, J. H. (November, 2002). Introduce them to Mary Anning: She's more than "seller of sea shells at the seashore." Paper presented at the 2002 national convention of the National Association of Biology Teachers, Cincinnati, OH.
- Goodhue, T. (2002). *The princess of paleontology: The life and times of Mary Anning*. Manuscript accepted for publication, Academica Press.
- Good, R. (1991). Editorial. *Journal of Research in Science Teaching*, 28, 387.
- Good, R., & Berger, C. (1998). The computer as a powerful tool for understanding science. In J. J. Mintzes, J. H. Wandersee, & J. D. Novak (Eds.), *Teaching science for understanding: A human constructivist view* (pp. 213-227). San Diego, CA: Academic Press.
- Good, R. G., & Wandersee, J. H. (1992). A voyage of discovery: Designing a graduate course on HPST. In S. Hills (Ed.), *History and philosophy of science in science education*, Volume I (pp. 423-434). Kingston, Ontario: Queen's University.
- Good, R. G., Wandersee, J. H., & St. Julien, J. (1993). Cautionary notes on the appeal of the new "ism" (constructivism) in science education. In K. Tobin (Ed.), *The practice of constructivism in science education* (pp. 71-87). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Gottschalk, L. (1965). *Understanding history: A primer of historical method*. New York: Alfred A. Knopf.
- Gould, S. J. (1987). *Time's arrow, time's cycle*. Cambridge, MA: Harvard University Press.
- Gould, S. J. (1998). Seeing eye to eye, through a glass clearly. In S. J. Gould *Leonardo's mountain of clams and the Diet of Worms* (pp. 57-73). New York: Harmony Books.
- Gowin, D. B. (1981). *Educating*. Ithaca, NY: Cornell University Press.
- Greenough, G. B. (1978). *A critical examination of the first principles of geology; In a series of essays*. New York: Arno Press Inc. (Original work published 1819)
- Guba, E. S., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (2nd ed., pp. 105-117). Thousand Oaks, CA: Sage Publications.
- Gunstone, R. F., & Mitchell, I. J. (1998). Metacognition and conceptual change. In J. J. Mintzes, J. H. Wandersee, & J. D. Novak (Eds.), *Teaching science for understanding: A human constructivist view* (pp. 133-163). San Diego, CA: Academic Press.

- Haile, N. (1997). The “piddling” school of geology. *Nature*, 387, 650.
- Hamblin, W. K., & Christiansen, E. H. (2001). *Earth's Dynamic System* (9th ed.). Upper Saddle River, NJ: Prentice Hall.
- Hankins, T. L. (1999). Blood, dirt, and nomograms: A particular history of graphs. *Isis*, 90, 50-80.
- Haskell, R. E. (2001). *Transfer of learning: Cognition, instruction, and reasoning*. San Diego, CA: Academic Press.
- Hawley, D. (1993). Field ‘sketches’ – Purpose, principles and practice. *Teaching Earth Sciences*, 18, 60-62.
- Hineline, M. L. (1993). The visual culture of the earth sciences, 1863-1970 (Doctoral dissertation, University of California, San Diego, 1993). *Dissertation Abstracts International*, 55, 713.
- Holmes, N. (1984). *Designer's guide to creating charts and diagrams*. New York: Watson-Guptill Publications.
- Holmes, N., & DeNeve, R. (1985). *Designing pictorial symbols*. New York: Watson-Guptill Publications.
- Howarth, R. J. (1998). Graphical methods in mineralogy and igneous petrology (1800-1935). In B. Fritscher & F. Henderson (Eds.), *Toward a history of mineralogy, petrology, and geochemistry* (pp.281-307). Munich: Institut für Geschichte der Naturwissenschaften.
- Humboldt, A. (1832). *Fragmente einer geologie und klimatologie Asiens*. Berlin: J. A. List.
- Humboldt, A. v., Ehrenberg, G., & Rose, G. (1837). *Reise nach dem Ural, dem Altai und dem Kaspischen Meere auf Befehl Sr. Majestät des Kaisers von Russland im jahre 1829*. Berlin: Verlag der Sanderschen Buchhandlung.
- Hutton, J. (1959). *Theory of the earth with proofs and illustrations*. Weinheim/Bergstr., Germany: H. R. Engelmann. (Original work published 1795)
- Hutton, J. (1970a). Abstract of a dissertation read in the Royal Society of Edinburgh, upon the seventh of March, and the fourth of April, M,DCC,-LXXXV, concerning the system of the earth, its duration, and stability. In G. W. White (Ed.) *Contributions to modern geology* (Vol. 5, pp. 1-30). Darien, CT: Hafner Publishing Co.(Original work published 1785)

- Hutton, J. (1970b). Theory of the earth; or an investigation of the laws observable in the composition, dissolution, and restoration of land upon the globe. In G. W. White (Ed.) *Contributions to modern geology* (Vol. 5, pp. 33-131). Darien, CT: Hafner Publishing Co. (Original work published 1788)
- Hutton, J. (1997). *Theory of the earth, with proofs and illustrations. Volume III.* (A. Geikie, Ed.) London: Geological Society. (Original work published 1899)
- Ivins, W. M., Jr. (1953). *Prints and visual communication*. London: Routledge & Kegan Paul Limited.
- Jenkins, E. (1989). Why the history of science? In M. Shortland & A. Warwick (Eds.), *Teaching the history of science* (pp. 19-29). Oxford: Basil Blackwell Ltd.
- Jones, R. E. (1979). Lunar eclipse diagrams. *School Science and Mathematics*, 79, 367-372.
- Kelly, G. J., Carlsen, W. S., & Cunningham, C. M. (1993). Science education in sociocultural context: Perspectives from the sociology of science. *Science Education*, 77, 207-220.
- Kerlinger, F. N. (1986). *Foundations of behavioral research*. New York: Holt, Rinehart, & Winston.
- Klein, M. J. (1972). Use and abuse of historical teaching in physics. In S. G. Brush & A. A. L. King (Eds.), *History in the teaching of physics*, (pp. 12-27). Hanover, NH: University Press of New England.
- Knell, S. J. (2000). *The culture of English geology, 1815-1851: A science revealed through its collecting*. Aldershot, England: Ashgate Publishing Limited.
- Lacoste, P. F. (1805). *Lettres minéralogiques et géologiques sur les volcans de l'Auvergne : écrites dans un voyage fait en 1805*. Clermont: Landriot.
- Latour, B. (1990). Drawing things together. In M. Lynch & S. Woolgar (Eds.), *Representation in scientific practice* (pp. 19-68). Cambridge, MA: MIT Press.
- Leblond, J. B. (1824). *Description de la Guyane Française, or tableau des productions naturelles et commerciales de Cette Colonie*. Paris: A. Eymery.
- Lecoq, H. (1838). *Éléments de géologie et d'hydrographie, ou resume des notions acquises sur les grandes lois de la nature faisant suite et servant de complément aux éléments de géographie physique et de météorologie*. Paris: J. -B. Bailliere.
- Leddy, A. (1981). A portrait of the artist and geologist as a young man: Henry De la Beche (1796-1855). *Journal of the Harker Geological Society*, 12, 37-41.

- Levie, W. H., & Lentz, R. (1982). Effects of text illustrations: A review of research. *Educational Communication and Technology*, 30, 195-232.
- Lincoln, Y. S., & Guba, E. G. (1985). *Naturalistic inquiry*. Beverly Hills, CA: Sage.
- Lincoln, Y. S., & Guba, E. G. (2000). The discipline and practice of qualitative research. In N. K. Denzin (Ed.) *Handbook of qualitative research* (2nd ed.) (pp. 1-28). Thousand Oaks, CA: Sage Publications.
- Lucas, M. (2000). Getting Tufte. *Mappa Mundi Magazine*. Retrieved from June 26, 2001 from <http://mappa.mundi.net/trip-m/tufte/>
- Lutgens, F. K., & Tarbuck, E. J. (2000). *Essentials of geology* (7th ed.). Upper Saddle River, NJ: Prentice Hall.
- Lutgens, F. K., & Tarbuck, E. J. (2002). *Foundations of earth science* (3rd ed.). Upper Saddle River, NJ: Prentice Hall.
- Lyell, C. (1838). *Elements of geology*. London: John Murray.
- Lyell, C. (1991). *Principles of geology, being an attempt to explain the former changes of the earth's surface, by reference to causes now in operation, volumes I, II, & III*. Chicago: University of Chicago Press. (Original work published 1830-1833)
- Maccullough, J. (1821). *A geological classification of rocks, with descriptive synopses of the species and varieties comprising the elements of practical geology*. London: Longman, Hurst, Rees, Orme, and Brown.
- Macgillivray, W. (1840). *A manual of geology*. London: Scott, Webster, and Geary.
- Mantell, G. (1822). *The fossils of the South Downs, or the illustrations of the fossils of Sussex*. London: L. Relfe.
- Mantell, G. (1833). *The geology of the south-east of England*. London: Longman, Rees, Orme, Brown, Green, and Longman.
- Mantell, G. (1836). *Thoughts on a pebble, or a first lesson in geology*. London: Relfe and Fletcher.
- Mantell, G. (1838). *The wonders of geology*. London: Relfe and Fletcher.
- Mather, K. F., & Mason, S. L. (1939). *A source book in geology*. New York: McGraw-Hill Book Company, Inc.
- Matthews, M. R. (1994). *Science teaching: The role of history and philosophy in science*. New York: Routledge.

- Matthews, M. R. (1999). Social constructivism and mathematics education: Some comments. *Philosophy of Education*. Retrieved from [http://www.ed.uiuc.edu/EPS/PES-yearbook/1999/matthews\\_body.asp](http://www.ed.uiuc.edu/EPS/PES-yearbook/1999/matthews_body.asp)
- Mawe, J. (1825). *Familiar lessons on mineralogy and geology* (7th ed.). London: Longman, Hurst, Rees, Orme, Browne, & Green.
- Mayer, R. E., & Anderson, R. B. (1991). Animations need narrations: An experimental test of a dual-coding hypothesis. *Journal of Educational Psychology*, 83, 484-490.
- Mayer, R. E., & Gallini, J. K. (1990). When is an illustration worth ten thousand words? *Journal of Educational Psychology*, 82, 715-726.
- McCartney, P. J. (1976). Henry De la Beche: A new kind of geologist. *Amgueddfa*, 21, 13-28.
- McCartney, P. J. (1977). *Henry De la Beche: Observations on an observer*. Cardiff: Friends of the National Museum of Wales.
- McClelland, J. (1984). Alternative frameworks: Interpretation of evidence. *European Journal of Science Education*, 6, 1-6.
- McGeary, D., Plummer, C., & Carlson, D. (2001). *Physical geology: The earth revealed* (4th ed.) Boston: McGraw-Hill.
- Mease, J. (1807). *A geological account of the United States comprehending a short description of their animal, vegetables, and mineral productions, antiquities, and curiosities*. Philadelphia: Birch and Small.
- Mintzes, J. J., & Novak, J. D. (2000). The epistemological Vee diagram. In J. J. Mintzes, J. H. Wandersee, & J. D. Novak (Eds.) *Assessing science understanding* (pp. 41-69). San Diego, CA: Academic Press.
- Mintzes, J. J., & Wandersee, J. H. (1998). Reform and innovation in science teaching: A human constructivist view. In J. J. Mintzes, J. H. Wandersee, & J. D. Novak (Eds.), *Teaching science for understanding: A human constructivist view* (pp. 29-58). San Diego, CA: Academic Press.
- Mintzes, J. J., Wandersee, J. H., & Novak, J. D. (1998). Preface. In J. J. Mintzes, J. H. Wandersee, & J. D. Novak (Eds.), *Teaching science for understanding: A human constructivist view* (pp. xvii-xx). San Diego, CA: Academic Press.
- Moore, N. F. (1834). *Ancient mineralogy; or, an inquiry respecting mineral substances mentioned by the ancients; with occasional remarks on the uses to which they were applied*. New York: G. & C Carvill & Co.

- Monaghan, N. T. (2001). Irish paleontological illustrations of the 19th century. In B. S. Rushton, P. Hackney, & C. R. Tyrie (Eds.), *Biological collections and biodiversity* (pp. 83-90). Otley, England: Westbury.
- Monroe, J. S., & Wicander, R. (1997). *The changing earth: Exploring geology and evolution* (2nd ed.). Belmont, CA: West/Wadsworth.
- Monroe, J. S., & Wicander, R. (2001a). *The changing earth: Exploring geology and evolution* (3rd ed.). Pacific Grove, CA: Brooks/Cole.
- Monroe, J. S., & Wicander, R. (2001b). *Physical geology: Exploring the earth* (4th ed.). Pacific Grove, CA: Brooks/Cole.
- Moseley, F. (1991). Aerial photographs in geological map interpretation and in field geology. *Teaching Earth Science*, 15, 36-44.
- Moseley, F. (1992). Field sketches. *Teaching Earth Science*, 17, 61-63.
- Murchison, R. (1839). *The Silurian System, founded on geological researches in the counties of Salop, Hereford, Radnor, Montgomery, Caermarthen, Brecon, Pembroke, Mommouth, Gloucester, Worcester, and Stafford; with descriptions of the coal-fields and overlying formations*. London: John Murray.
- Murray, J. (1802). *A comparative view of Huttonian and Neptunian systems of geology*. Edinburgh: Ross and Blackwood.
- The Museum of Economic Geology. (1848, April). *Illustrated London News*. Archived document (NMW 2230). Retrieved July 10, 2002 from Cardiff: National Museum of Wales.
- The Museum of Practical Geology (1851, May). *Illustrated London News*. Archived document (NMW 2231). Retrieved July 10, 2002 from Cardiff: National Museum of Wales.
- National Academy of Sciences (1995). Science Content Standards. In *National Science Education Standards* (chap. 6) Retrieved from <http://www.nap.edu/readingroom/books/nse>
- National Association of Geoscience Teachers. (n.d.) *Welcome to the National Association of Geoscience Teachers Homepage*. Retrieved April 11, 2002, from <http://www.nagt.org/>
- North, F. J. (1944). Geology's debt to Henry Thomas de la Beche. *Endeavor*, 3, 15-19.
- Novak, J. D. (1977). *A theory of education*. Ithaca, NY: Cornell University Press.

- Novak, J. D. (1998). The pursuit of a dream: Education can be improved. In J. J. Mintzes, J. H. Wandersee, & J. D. Novak (Eds.), *Teaching science for understanding: A human constructivist view* (pp. 3-28). San Diego, CA: Academic Press.
- Novak, J. D., & Gowin, D. B. (1984). *Learning how to learn*. Cambridge University Press: Cambridge, England.
- Novak, J. D., Mintzes, J. J., & Wandersee, J. H. (2000). Learning, teaching, and assessment: A human constructivist perspective In J. J. Mintzes, J. H. Wandersee, & J. D. Novak (Eds.), *Assessing science understanding: A human constructivist view* (pp. 1-13). San Diego, CA: Academic Press.
- Omalius d'Halloy, J. B. J. (1831). *Éléments de géologie*. Paris: Levrault.
- Omalius d'Halloy, J. B. J. (1833). *Introduction à la géologie, ou première partie des élémens d'histoire naturelle inorganique, contenant des notions d'astronomie, de météorologie et de minéralogie*. Paris: F. G. Levrault.
- Orion, N., Ben-Chaim, D., & Kali, Y. (1997). Relationship between earth-science education and spatial visualization. *Journal of Geoscience Education*, 45, 129-132.
- Paivio, A. (1971). *Imagery and verbal processes*. New York: Holt, Rinehart, and Winston, Inc.
- Paivio, A. (1974). Language and knowledge of the world. *Educational Researcher*, 3, 5-12.
- Paivio, A. (1989). A dual coding perspective on imagery and the brain. In J. W. Brown (Ed.), *Neuropsychology of visual perception* (pp. 203-216). Hillsdale, NJ: Lawrence Erlbaum Associates.
- Paivio, A. (1991). Dual Coding Theory: Retrospect and current status. *Canadian Journal of Psychology*, 45, 255-287.
- Paivio, A., & Csapo, K. (1973). Picture superiority in free recall: Imagery or dual coding? *Cognitive Psychology*, 5, 176-203.
- Parkinson, J. (1804). *Organic remains of a former world. An examination of the mineralized remains of the vegetables and the animals of the antediluvian world; generally termed extraneous fossils; first volume; containing the vegetable kingdom*. London: J. Robson, J. White, and J. Murray.
- Parkinson, J. (1808). *Organic remains of a former world. An examination of the mineralized remains of the vegetables and the animals of the antediluvian world; generally termed extraneous fossils; second volume; containing the fossil Zoophytes*. London: Nornaville and Fell.



- Parkinson, J. (1811). *Organic remains of a former world. An examination of the mineralized remains of the vegetables and the animals of the antediluvian world; generally termed extraneous fossils; third volume; containing the fossil starfish, echini, shells, insects, amphibia, mammalia, &c.* London: Sherwood, Neely, and Jones.
- Parkinson, J. (1822). *Outlines of oryctology: An introduction to the study of fossil organic remains; especially of those found in the British strata; intended to aid the student in his enquiries respecting the nature of fossils, and their connection with the formation of the earth.* London: James Parkinson.
- Parsons, H. L. (1965). The relationship and importance of graphical representation to learning (Doctoral dissertation, Montana State University, 1965). *Dissertation Abstracts International*, 26, 3761.
- Patton, M. Q. (1990). *Qualitative evaluation and research methods* (2nd ed.). Newbury Park, CA: Sage.
- Phillips, J. (1835). *A guide to geology* (2nd ed.). London: Longman, Rees, Orme, Brown, Green, and Longman.
- Phillips, J. (1840). Letter to Henry T. De la Beche. Archived document (NMW 1339). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- Phillips, J. (1842a). Letter to Henry T. De la Beche. Archived document (NMW 1470). Retrieved July 10, 2002 from Cardiff: National Museum of Wales.
- Phillips, J. (1842b). Letter to Henry T. De la Beche. Archived document (NMW 1484). Retrieved July 9, 2002 from Cardiff: National Museum of Wales.
- Phillips, W. (1815). *An outline of mineralogy and geology, intended for the use of those who may desire to become acquainted with the elements of those sciences; especially of young persons.* London: William Phillips.
- Phillips, W. (1823). *An elementary introduction to the knowledge of mineralogy: Comprising some account of the characters and elements of minerals; explanations of terms in common use; descriptions of minerals, with accounts of the places and circumstances in which they are found; and especially the localities of British minerals* (3rd ed.). London: W. Phillips.
- Pinker, S. (1997). *How the mind works*. New York: W. W. Norton & Company.
- Playfair, J. (1956). *Illustrations on the Huttonian theory of the earth*. New York: Dover Publications, Inc. (Original work published 1802)
- Playfair, J. (1970). Biographical account of the late Dr James Hutton, F. R. S. Edin. In G. W. White (Ed.) *Contributions to modern geology, Volume 5* (pp. 143-203). Darien, CT: Hafner Publishing Co. (Original work published 1803)

- Plummer, C. C., & McGeary, D. (1996). *Physical geology* (7th ed.). Dubuque, IA: Times Mirror Higher Education Group.
- Porter, R. (1977). *The making of geology: Earth science in Britain, 1660-1815*. London: Cambridge University Press.
- Price, D. (1986). Mary Anning specimens in the Sedgwick Museum, Cambridge. *Geological Curator*, 4, 319-324.
- Reboul, H. (1833). *Géologie de la Période Quaternaire et introduction a l'histoire ancienne*. Paris: F. G. Levrault.
- Reboul, H. (1835). *Essai de géologie descriptive et historique prolégomnes et Période Primaire*. Paris: F. G. Levrault.
- Revolution in Earth and Space Science Education. (n.d.) *Executive summary, blueprint for change: Report from the National Conference on the Revolution in Earth and Space Science Education*. Retrieved September 3, 2002 from <http://www.earthscienceeducationrevolution.org/acknowledge/acknowledge01.cfm>
- Reyment, R. A. (1996). Geogiants: Henry Thomas De la Beche. *Terra Nova*, 8, 489-492.
- Rieck, W. A. (1999). *Teaching in secondary schools* (2nd ed.). Dubuque, IA: Kendall/Hunt Publishing Company.
- Robinson, A. (1993). *What smart students know*. New York: Three Rivers Press.
- Roy, E. C., Jr. (2002). Earth science in Texas: A progress report. *Geotimes*, 47, 24-25.
- Rudwick, M. J. S. (1963). The foundation of the Geological Society of London. *British Journal of the History of Science*, 1, 177-135.
- Rudwick, M. J. S. (1975). Caricature as a source for the history of science: De la Beche's anti-Lyellian sketches of 1831. *Isis*, 66, 534-560.
- Rudwick, M. J. S. (1976). The emergence of a visual language for geological science 1760-1840. *History of Science*, 14, 149-195.
- Rudwick, M. J. S. (1979). The Devonian: a system born from conflict. *Special Papers in Paleontology*, 23, 9-21.
- Rudwick, M. J. S. (1985). *The great Devonian controversy: The shaping of scientific knowledge among gentlemanly specialists*. Chicago: University of Chicago Press.
- Rudwick, M. J. S. (1988). A year in the life of Adam Sedgwick and company, geologists. *Archives of Natural History*, 15, 243-268.

- Rudwick, M. J. S. (1992). *Scenes from deep time: Early pictorial representations of the prehistoric world*. Chicago: University of Chicago Press.
- Rudwick, M. J. S. (1996). Cuvier and Brongniart, William Smith, and the reconstruction of geohistory. *Earth Sciences History*, 15, 25-36.
- Rudwick, M. J. S. (1997). *Georges Cuvier, fossil bones, and geological catastrophes*. Chicago: University of Chicago Press.
- Rudwick, M. J. S. (1998). Lyell and the *Principles of Geology*. In D. J. Blundell & A. D. Scott (Eds.) *Lyell: The past is the key to the present* (pp. 3-15). London: Geological Society.
- Rudwick, M. J. S. (2000). The papers of H. T. De la Beche (1796-1855) in the National Museum of Wales (Review). *Isis*, 91, 840.
- Schiebinger, L. (1987). The history and philosophy of women in science: A review essay. *Signs: Journal of Women in Culture and Society*, 12, 305-332.
- Schwab, J. J. (1962). The concept of the structure of a discipline. *Educational Record*, 43, 197-205.
- Scrope, G. P. (1825). *Considerations on volcanoes: The probable causes of their phenomena, the laws which determine their march, the disposition of their products, and their connexion with the present state and past history of the globe; leading to the establishment of a new theory of the earth*. London: W. Phillips.
- Scrope, G. P. (1827). *Memoir on the geology of central France, including the volcanic formations of Auvergne, the Velay, and the Vivarrais*. London: Longman, Rees, Orme, Brown, and Green.
- Sedgwick, A. (1830). Letter to Henry T. De la Beche. Archived document (NMW 1870). Retrieved July 10, 2002 from Cardiff: National Museum of Wales.
- Sedgwick, A. (1843). Letter to Henry T. De la Beche. Archived document (NMW 1881). Retrieved July 10, 2002 from Cardiff: National Museum of Wales.
- Sgarbi, C. (1993). Between words and drawings: Dissertation on a newly found illustrated version of "De Architectura" (Doctoral dissertation, University of Pennsylvania, 1993). *Dissertation Abstracts International*, 54, 711.
- Sharpe, T. (1997). The archive of H. T. De la Beche (1796-1855) in the National Museum of Wales, Cardiff, UK. *Journal of the Geological Society of Jamaica*, 32, 29-35.
- Sharpe, T. (1998-1999). Papers from the past. *Amgueddfa*, 2, 16-19.

- Sharpe, T., & McCartney, P. J. (1998). *The papers of H. T. De la Beche (1796-1855) in the National Museum of Wales*. Cardiff: National Museum of Wales.
- Sheets-Pyenson, S. (1982). Geological communication in the nineteenth century: the Ellen S. Woodward autograph collection at McGill University. *Bulletin of the British Museum (Natural History) Historical Series*, 10, 179-226.
- Sheets-Pyenson, S. (1985). Popular science periodicals in Paris and London: The emergence of a low scientific culture, 1820-1875. *Annals of Science*, 42, 549-572.
- Silliman, (Ed.) (1829). Outline of the course of geological lectures, given at Yale College. In R. Bakewell *An introduction to geology: Comprising the elements of the science in its present advanced state, and all the recent discoveries; with an outline of the geology of England and Wales* (3rd ed.). New Haven, CT: Hezekiah Howe.
- Smith, M. (2002). Cornerstones of the revolution in earth science education. *Geotimes*, 47, 5.
- Smith, R. (1812). *Geological and phisiological disquisition*. Cincinnati, OH: Browne.
- Smith, W. (1817). *Stratigraphical system of organized fossils with reference to the specimens of the original geological collection in the British Museum: explaining their state of preservation and their use in identifying the British strata*. London: E. Williams.
- Sollas, W. J. (1905). *The age of the earth and other geological studies*. London: Fisher Unwin.
- Solomon, J. (1989). Teaching the history of science: Is nothing sacred? In M. Shortland & A. Warwick (Eds.), *Teaching the history of science*, (pp. 42-53). Oxford: Basil Blackwell Ltd.
- Sproull, J. (1991). Advanced technologies for the study of earth systems. *Science Activities*, 28, 19-22.
- Starko, A. J. (1995). *Creativity in the classroom: Schools of curious delight*. White Plains, NY: Longman Publishers.
- Steinberg, S. H. (1996). *Five hundred years of printing* (4th Rev. ed. by J. Trevitt). New Castle, DE: Oak Knoll Press and The British Library.
- Suchting, W. A. (1994). Notes on the cultural significance of the sciences. *Science and Education*, 3, 1-57.
- Tashakkori, A., & Teddlie, C. (1998). *Mixed methodology: Combining qualitative and quantitative approaches*. Thousand Oaks, CA: Sage Publications.

- Thomson, T. (1836). *Outlines of mineralogy, geology, and mineral analysis*. London: Baldwin & Cradock.
- Tilling, L. (1975). Early experimental graphs. *The British Journal for the History of Science*, 8, 193-213.
- Torrens, H. (1995). Mary Anning (1799-1847) of Lyme; 'the greatest fossilist the world ever knew.' *The British Journal for the History of Science*, 28, 257-285.
- Trowbridge, J. E., & Wandersee, J. H. (1998). Theory-driven graphic organizers. In J. J. Mintzes, J. H. Wandersee, & J. D. Novak (Eds.), *Teaching science for understanding: A human constructivist view* (pp. 95-131). San Diego, CA: Academic Press.
- Tufte, E. R. (1990). *Envisioning information*. Cheshire, CT: Graphics Press.
- Tufte, E. R. (1997). *Visual explanations: Images and quantities, evidence and narrative*. Cheshire, CT: Graphics Press.
- Tufte, E. R. (2001). *The visual display of quantitative information*. Cheshire, CT: Graphics Press. (Original work published 1983)
- University College London (2002). *Active UK Map*. Retrieved September 17, 2002 from <http://www.ukguide.org/ukmap.html>
- Ure, A. (1829). *A new system of geology, in which the great revolutions of the earth and animated nature are reconciled at once to modern science and sacred history*. London: Longman, Rees, Orme, Brown, & Green.
- Vaccari, E. (1998). Lyell's reception on the continent of Europe: A contribution to an open historiographical problem. In D. J. Blundell & A. D. Scott (Eds.) *Lyell: The past is the key to the present* (pp. 39-52). London: Geological Society.
- Von Buch, L. (1820). *Ueber einen vulcanischen Ausbruch auf der Insel Lanzerote*. Berlin: Akademie der Wissenschaften.
- Wandersee, J. H. (1986). Can the history of science help science educators anticipate students' misconceptions? *Journal of Research in Science Teaching*, 23, 581-597.
- Wandersee, J. H. (2000). Using concept mapping as a knowledge mapping tool. In K. M. Fisher, J. H. Wandersee, & D. E. Moody (Eds.), *Mapping biology knowledge* (pp. 127-142). Dordrecht, Netherlands: Kluwer Academic Publishers.
- Wandersee, J. H., Mintzes, J. J., & Novak, J. D. (1994). Research on alternative conceptions in science. In D. L. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 177-210). New York: Macmillan Publishing Company.

- Wandersee, J. H., & Roach, L. M. (1998). Interactive historical vignettes. In J. J. Mintzes, J. H. Wandersee, & J. D. Novak (Eds.), *Teaching science for understanding: A human constructivist view* (pp. 281-306). San Diego, CA: Academic Press.
- Wang, H. S., & Schmidt, W. H. (2001). History, philosophy, and sociology of science in science education: Results from the third International Mathematics and Science Study. *Science and Education*, 10, 51-70.
- Watson, M. E., & Tucci, W. (2002). A victory for earth science: How a group of determined people made earth science a graduation requirement in North Carolina. *Geotimes*, 47, 20-22.
- Weisberg, J. S. (1969). The use of visual advance organizers for learning earth science concepts (Doctoral dissertation, Columbia University, 1969). *Dissertation Abstracts International*, 30, 3867.
- Whitaker, M. A. B. (1979). History and quasi-history in physics education part II. *Physics Education*, 14, 239-242.
- White, G. C. (1978). *Essays on the history of geology*. New York: Arno Press.
- White, R., & Gunstone, R. (1992). *Probing understanding*. London: Falmer Press.
- Winchester, S. (2001). *The map that changed the world*. New York: HarperCollins Publishers.
- Woodward, H. B. (1907). *The history of the Geological Society of London*. London: Geological Society Burlington House.
- Woodward, H. B. (1911). *A history of the sciences. History of geology*. New York: G. P. Putnam's Sons.
- Wyllie, P. (1999). Hot little crucibles are pressured to reveal and calibrate igneous processes. In G. Y. Craig & J. H. Hull (Eds.), *James Hutton – Present and Future* (pp. 37-57). London: Geological Society.
- Yancey, J. M. (1972). Graphical representation of abstract concepts in textual materials. (Doctoral dissertation, The Pennsylvania State University, 1972). *Dissertation Abstracts International*, 34, 1146-A.

## Appendix A: Pilot Study

I selected a proposed dissertation topic in August 2001, the focus of which was to investigate the connection between James Hutton's original 1795 book promoting uniformitarianism as the process responsible for the earth's current landscape, and John Playfair's *Illustrations of the Huttonian Theory of the Earth*. Although Hutton is referenced as the Father of Modern Geology in many introductory college geology textbooks, his ideas and concepts did not gain early acceptance. The initial belief guiding this study was that Playfair's graphic illustrations might have had a tremendous effect in promoting Hutton's ideas. Another interesting connection was that John Playfair was the uncle and guardian of William Playfair, who is noted by Edward R. Tufte as a prominent contributor to modern graphic representation. I had never heard of John Playfair while enrolled in my Master's program of study in geology, however, since most geology books do not mention him. Instead, Charles Lyell is given credit for promoting many of Hutton's original ideas.

### Initial Investigation

At the beginning of the fall semester of 2001, the overriding thought in my mind was to find an original copy of John Playfair's *Illustrations of the Huttonian Theory of the Earth*, and investigate whether Playfair's use of illustrations had gained a wider audience for Hutton's geologic concepts at the beginning of the 19th century. I planned to locate Playfair's book, begin an analysis of his graphic illustrations using Edward R. Tufte's principles of graphic design, and interpret the graphics' importance to the modern geology classroom using the Theory of Human Constructivism. Comparisons between Hutton's and Lyell's early geology texts were also to be made.

## Locating Early Geology Texts

I requested Hutton's original 1795 two-volume book, *Theory of the Earth*, through interlibrary loan services (ILL) along with his 1788 paper, also entitled *Theory of the Earth*. Playfair's *Illustrations of the Huttonian Theory of the Earth* and Charles Lyell's original 1830, 1832, and 1833 volumes of *Principles of Geology* were also requested. Dr. Wandersee, my major professor, electronically mailed a list of rare book sites to me, and I also began searching through the sites for possible copies of these books. The sites searched were

- <http://www.amazon.com/exec/obidos/ASIN/0820115061/atriumA/103-6166573-1742216>
- <http://www.amazon.com/exec/obidos/ASIN/0801426669/atriumA/103-6166573-1742216>
- <http://www.jthin.co.uk/scoth.htm>
- <http://www.talbot1.com/usedbook.htm>
- <http://www.soton.ac.uk/~imw/bookdir.htm>
- <http://www.uni-wuerzburg.de/mineralogie/palbot/literature/books.html>
- <http://www.connectotel.com/books/wwwbs.html>
- <http://www.bright.net/~amsbooks/>
- <http://www.bountifulbooks.com/>
- <http://www.elephantbooks.com/>
- <http://www.powells.com/>
- <http://www.abebooks.com/home/zeppelin/>
- <http://www.ed.ac.uk/altc2001/programme/playfair.html>



- <http://www.lib.ed.ac.uk/lib/about/pubs/lg51/coll/science.shtml>

I found [www.talbot1.com/usedbook.htm](http://www.talbot1.com/usedbook.htm) to be the most helpful site of those listed above.

I did manage to locate and order a facsimile version of Playfair's text, but a fairly exhaustive search yielded no copies of either Hutton's or Lyell's original works.

However, Dr. Brian Lock, Head of the Geology Department of University of Louisiana at Lafayette, had facsimile copies of Lyell's texts, which I borrowed. An initial review of the facsimile version of Lyell's *Principles of Geology* revealed fairly simple line drawings that were incorporated directly into the text.

### **Theory of Human Constructivism**

An investigation into the Theory of Human Constructivism, in whose principles I planned to analyze the value of the graphics uncovered for the modern geology classroom, began with a chapter written by Wandersee, Mintzes, and Novak in *Handbook of Research on Science Teaching and Learning*. The chapter, "Research on Alternative Conceptions in Science," gave an overview of human constructivism.

### **Internet and Library Research**

The Internet was also searched at this time for the geological contributions of Hutton, Lyell, and Playfair. Several websites were located, including

- <http://www.geolsoc.org.uk/template.cfm?name=links>
- <http://www.turnpike.net/~mscott/delabeche.htm>
- [http://jefferson.village.virginia.edu/~meg3c/id/id\\_disc\\_15divonian.html](http://jefferson.village.virginia.edu/~meg3c/id/id_disc_15divonian.html)
- [http://www.thedorsetpage.com/people/Mary\\_Annings.htm](http://www.thedorsetpage.com/people/Mary_Annings.htm)
- <http://www.strangescience.net/hutton.htm>
- [http://www.ge-at.iastate.edu/courses/Geol\\_100/angular.html](http://www.ge-at.iastate.edu/courses/Geol_100/angular.html)
- <http://www.xrefer.com/entry/617815>

- <http://www.xrefer.com/entry/615336>
- <http://www-groups.dcs.st-andrews.ac.uk/~history/References/Playfair.html>

Websites mentioned Hutton's difficult writing style, Playfair's simplification of Hutton's ideas, and Lyell's role in promoting the concept of uniformitarianism, which simply stated is, "the present is the key to the past." Several books were also located in Louisiana State University's (LSU) Middleton Library, including Bailey's (1967) *James Hutton – The Founder of Modern Geology*, and Craig and Hull's (1999) *James Hutton – Present and Future*.

### A Change in Focus

My disappointment was great when the facsimile version of Playfair's *Illustrations of the Huttonian Theory of the Earth* arrived from a Barnes and Noble used book dealer. There were *no* graphics in the text! Playfair obviously used the term "illustrations" as "descriptions," "explanations," and "expansions." It appeared that the reason Playfair enjoyed success in promoting Hutton's ideas was due to his organization and language. A second facsimile copy of Playfair's book did arrive via interlibrary loan from University of California at Santa Barbara; this copy verified that there were no graphics included. The focus of the pilot study shifted from an investigation of Playfair's graphics in promoting the Huttonian theory, to an investigation into the emergence of early geology graphics, and what these graphics' potential might be in the geology classroom today. Dr. Wandersee and I agreed that the graphic focus should *not* include early fossil depictions, crystallographic structures, or maps, since all of these graphics belonged primarily to fields of study that were not truly representative of what is considered early modern geology. Paleontology is a discipline within biology,

mineralogy is a discipline within chemistry, and early maps had their beginnings in geography. Therefore, the early geology graphics investigated should incorporate structure of the earth, or other representations of the key principles of geology.

### **Review of Lyell's Texts**

I re-analyzed Charles Lyell's *Principles of Geology* from my borrowed facsimile versions. A microfiche copy of the books arrived from Rice University, and I was able to verify the correctness of the facsimile versions I had. Lyell's writing style, as I discovered, was much easier to decipher than Hutton's. Lyell also incorporated graphic illustrations in his text. My initial reaction, however, was that there were so *few* illustrations, especially in the first two volumes. (In volume I, there were 35 graphics included in 511 pages. In volume II, 10 graphics were included in 330 pages, while volume III became more "graphic-conscious" with the inclusion of 91 graphics within 398 pages.) Geology books have obviously become more graphics-oriented; most introductory geology textbooks are filled with pictures, illustrations, diagrams, and graphs depicting causal relationships.

### **Review of Hutton's Texts**

The next ILL arrival (on King Microprint) was *Theory of the Earth, or An Investigation of the Laws Observable in the Composition, Dissolution, and Restoration of Land Upon the Globe* by Hutton. This paper was published in 1788, and eventually became the first two chapters of Hutton's book, *Theory of the Earth, with Proofs and Illustrations* (published in 1795). This paper, interestingly enough, did have a few graphics at the end. (For some reason, Hutton appeared to be interested in septarian nodules, and devoted one of the two plates to their depiction.) Although I managed to read the paper, there is a lot of material that is superfluous. Ideas that eventually become

the “backbone” of modern geology are sprinkled among long prepositional phrases and descriptions; these appear to contribute little to the content of the paper.

Problems arose when I attempted to copy the 1788 Hutton graphics from the microprint card at Middleton Library. The printer attached to the opaque reader did not provide high-resolution copies. Therefore, I requested paper copies of Hutton’s 1788 paper through Interlibrary Loan. Unfortunately, no participating library in the system was able to provide this.

### **Identification of Early Geology Texts**

Sir Archibald Geikie’s *The Founders of Geology* (second edition, published in 1905) listed some early geological textbooks. Included in the list were *Lehrbuch der Mineralogie* (1801 – 1803) by R. A. Reuss; *Treatise on Geognosy* (1808) by R. Jameson; *Traite de Geognosie* by J. F. D’Aubuisson de Voisons; *Lehrbuch* by C. F. Naumann; *Elemens de Geologie and Abrege* by Omalius d’Halloy; *Institutions Geologiques* (1818) by Breislak; *Outlines* by Conybeare and Phillips; and *Manual of Geology* (1831), *Researches in Theoretical Geology* (1831), and *How to Observe in Geology* (1835) by H. T. De la Beche (1831). I next tried to procure as many of these texts as were available, either through Middleton Library or interlibrary loan.

Further Internet searches were conducted. Although I located sites describing some of the early scientists in the geological field, these were only identified through my prior knowledge. Searches on “early geological history,” “early geological texts,” and “early illustrations” yielded essentially nothing pertaining to early illustrations in the field. However, an extensive search of Middleton Library’s archives revealed *Dessin et Sciences XVII<sup>e</sup> – XVIII<sup>e</sup> Siècles* and *Images of Science: A History of Scientific Illustration* by Brian J. Ford. Although *Dessin et Sciences XVII<sup>e</sup> – XVIII<sup>e</sup> Siècles* did not prove to

have anything of value for this project, Ford's book briefly chronicled some of the illustrations in geology texts.

Dr. Brian Lock mentioned that his paleontology professor at Cambridge University, Dr. Martin Rudwick, had later become interested in the history of geology. Rudwick is the author of several papers and books on the history of geology, including *Scenes from Deep Time: Early Pictorial Representations of the Prehistoric World*. Therefore, attempts were made to contact Dr. Rudwick for his assistance in this research.

### **Cancellations**

The interlibrary loan staff informed me that many of the books I had requested had been cancelled. Some books were simply not available, while various lending institutions did not circulate some of the books. The cancelled books were

- Jean François Aubuisson de Voisins' *Traité de Géognosie oder Darstellung der jetzigen Kenntnisse* (University of Oklahoma and University of Illinois do not loan this book.)
- *Traité sur la structure extérieure du globe, ou, Institutions* by Scipion Breislak. (Harvard does not loan this book.)
- *Abrégé de Géologie* by Jean Julian Omalius d'Halloy (American Museum of Natural History in New York does not loan this book.)
- *Lehrbuch der Geognosie* by Carl Friedrich Naumann (Harvard does not loan this book.)

I tried to locate these books through the websites of used book dealers, but did not have any success.

## **Conybeare and Phillips**

The facsimile version of Conybeare and Phillips' *Outlines of the Geology of England and Wales, with an Introductory Compendium of the General Principles of that Science, and Comparative view of the Structure of Foreign Countries* arrived through Interlibrary Loan. This was the first geology text examined that was not authored by one of the original three geologists of focus (Hutton, Playfair, and Lyell). The book had 470 pages of text, six pages of preliminary notices, plus a 61-page introduction. There were only 23 pages of graphics, which I scanned as jpeg files on the highest resolution possible. A foldout map was printed in black and white, but was noted as being colored in the original text. Interestingly, I discovered that Greenough's geological map of England, commissioned through the Geological Society of London, was included in the book, and not William Smith's *original* geological map.

Arno Press published this facsimile version. At the end of the book, Arno Press included a flyer of other titles included in their History of Geology Series. I noted the ones of interest in my developing period of study, namely that time between the first published paper of Hutton (1788), and the time of Lyell's publications (1830s).

## **Identification of Other Early Geologic Authors**

Further investigation into the stacks of Middleton Library revealed other early geologic books. These books were investigated as to their graphic content, and to possible references to other early geologic texts.

**Bakewell.** An 1829 third edition of Bakewell's *An Introduction to Geology: Comprising the Elements of the Science in Its Present Advanced State, and All the Recent Discoveries; with an Outline of the Geology of England and Wales* was located. This rebound text included beautiful hand-tinted foldout maps. Seven plates were inserted at

the beginning of the text; the text included 400 pages, along with 20 pages of preface, table of contents, and a description of the plates. The plates were not incorporated in order, and perhaps were shuffled during the text's rebinding. I scanned the plates as high-resolution jpeg formats, and will refer this book to Elaine Smyth for the Hill Memorial Library.

**Phillips.** An 1852 posthumously published new edition of Phillips' *An Elementary Introduction to Mineralogy* was located. This book included many crystallographic illustrations in its 700 pages. However, since this book did not contain the original graphics by Phillips, it was not considered useful since it was published after the age of focus. I requested an earlier edition of Phillips' mineralogy text for study.

**Parkinson.** An unusually beautifully illustrated text of fossils was found in *Organic Remains of a Former World; An Examination of the Mineralized Remains of the Vegetables and Animals of the Antediluvian World; Generally Termed Extraneous Fossils* Volume III (of III), by James Parkinson (1811). This book should be protected at Hill Memorial Library! I was later able to locate Volumes I and II, published in 1804 and 1808 respectively. The third volume contained many fossil orders; there were 21 plates inserted at the end of the 455 pages of text, and 16 pages of preface, table of contents, and errata. The second volume, restricted to Zoophytes, contained 19 plates inserted behind 286 pages of text and 14 pages of index, preface, and advertisement. The first volume, fossils of the vegetable kingdom, contained only nine plates, and unlike the other two volumes, did not have a separate section of plate descriptions. This volume had 471 pages of text, along with 12 pages of preface and contents.

A second edition of these volumes, published in the 1830s, was later located in Middleton Library in Circulation Shelving. The colored plates were often different in

hues from the original publications, and in some cases, differed in level of detail (or carefulness) of brushstrokes. I preferred the original versions to the second editions, and scanned the original images as high-resolution jpeg files.

Another, later Parkinson publication was also discovered: *Outlines of Oryctology: An Introduction to the Study of Fossil Organic Remains; Especially of those Found in the British Strata: Intended to Aid the Student in his Enquiries Respecting the Nature of Fossils, and Their Connection with the Formation of the Earth* (1822). None of the 10 plates within this book were colored. Parkinson intended for this text to be the companion to the Conybeare and Phillips' (1822) text.

**Greenough.** A collection of essays by George Bellas Greenough, once President of the Geological Society of London, was located. This book, *A Critical Examination of the First Principles of Geology in a Series of Essays*, was a 1978 facsimile version of the original 1819 publication. No graphics were included.

### **Early Books of Geological History**

Two books by Horace Woodward were found at Middleton Library that outlined the early history of geology and the Geological Society of London. Woodward published *History of Geology* in 1911, and included biographies accompanied by plates of pictures and artistic renditions of the early geologists. Earlier in 1907, Woodward published *The History of the Geological Society of London*. Both these texts later proved to offer insight, names, and publications of the early period of modern geology.

### **Rare Book Collections**

The Hill Memorial Library on LSU's campus contains several rare book collections. I was able to visit this library, and review an original copy of the 1822



*Outline of the Geology of England and Wales* by Conybeare and Phillips. Unfortunately, the colored foldout map and sections were missing.

I also reviewed the 1818 *Essay on the Theory of the Earth by M. Cuvier with Mineralogical Notes and an Account of Cuvier's Geological Discoveries by Professor Jameson to which are now added Observations on the Geology of North America Illustrated by the Description of Various Organic Remains Found in that Part of the World* by Samuel L. Mitchell. There were no illustrations in either the Cuvier or Jameson sections of the book, but a total of eight plates of fossil renditions were in the Mitchell section.

Two other interesting texts in early geology emerged at Hill Memorial. Parker Cleaveland's 1816 text, *An Elementary Treatise on Mineralogy and Geology Being an Introduction to the Study of These Sciences and Designed for the Use of Pupils – For Persons, Attending Lectures on These Subjects, and as a Companion for Travellers in the United States of America*. This book contained six plates, five of which are crystal geometries, and one plate of the geological map of the United States. I also located and reviewed *Reliquiæ; or Observations on the Organic Remains Contained in Caves, Fissures, and Diluvial Gravel, and on Other Geological Phenomena, Attesting the Action of an Universal Deluge* by Reverend William Buckland (1824, 2nd edition). This was obviously the product of a catastrophist! The bindings on this book were beautiful, with swirls of color on the cover and page edges. The book contained 27 plates, and a table at the end. Most of the graphics are of fossils found in caves.

Elaine Smyth, Curator of Special Collections at Hill Memorial, was very helpful with my search for early, illustrated geology texts. Although she did not know a universally recognized word for illustrations within early texts (since “illustration” to

Playfair did not mean graphics), Ms. Smyth was able to give me instructions on how to search the LSU Library catalog for early texts that had illustrations included.

## Further Research into Early Geologic Texts

### Early Geologic Texts Identified

Using Elaine Smyth's directions for searching the LSU Library system, I was able to locate several additional early texts in geology. Interlibrary loan requests began arriving quite regularly also.

**James Hutton.** A 1959 facsimile version of James Hutton's 1795 book, *Theory of the Earth with Proofs and Illustrations*, arrived through interlibrary loan. Volume one contained four plates in addition to 620 pages of text, while volume two contained two plates in addition to 567 pages of text. Two of the plates in volume one were identical to Hutton's 1788 plates illustrating septarian nodules and granite, while two others offered cross sectional views of strata. The second volume contained two plates of finely drawn and illustrated mountains. I later discovered that Hutton took these from Saussure's earlier work, but did not adequately reference the plates in the text. All the plates were scanned and saved as high-resolution jpeg files.

**Nathaniel Fish Moore.** Moore's 1834 text, *Ancient Mineralogy: or, An Inquiry Respecting Mineral Substances Mentioned by the Ancients: with Occasional Remarks on the Uses to Which They Were Applied* arrived through interlibrary loan. However, there were no graphics or illustrations within the 191 pages of text.

**Henry T. De la Beche.** De la Beche's work emerged as important and prominent in the geological community as interlibrary loans began arriving, and additional texts were located in Middleton Library. The first De la Beche text to be reviewed was *Manuel Géologique*, published as a second edition in 1833. In the 721 pages of text (with

an additional two pages of errata and 19 pages of introduction), there were 58 pages containing graphics. The total number of figures included in this French version was 107. This was definitely the most graphic-prolific text uncovered thus far in the age of focus! As I would soon discover, this was also a well-known book of its time: I located another French version (1832), English versions (1831 and 1832, with only 104 graphics), and an 1834 German version with a reduced number of 24 figures. All of the graphics were scanned and saved in high-resolution jpeg files. The captions of the extra three graphics included in the French versions were translated into English. They depicted reconstructed scenes of ancient life.

De la Beche's 1835 *How to Observe Geology* also incorporated many graphics: within the 312 pages of text, and the eight pages of advertisements of contents, 138 woodcuts were included. An English (1837) and a French (1838) version of *Researches in Theoretical Geology* were also analyzed. The 46 graphics included in both texts were identical. All of De la Beche's graphics were scanned as high-resolution jpeg files.

### **Dissertation Abstracts**

The website for Dissertation Abstracts (<http://www.umi.com>) was searched for possible dissertations that were relevant to this study. Nineteen potentially valuable dissertations were identified on the website, and the abstracts for these were retrieved through Middleton Library and electronic database searches. Of the 19 dissertations, four were identified as prospective contributions to this study, and were ordered through interlibrary loan:

- Weisberg, Joseph Simpson, *The Use of Visual Advance Organizers for Learning Earth Science Concepts*, 1969

- Sgarbi, Claudio, Between words and drawings: Dissertation on a newly found illustrated version of '*De Architectura*,' 1993
- Parsons, Henry Lehner, The Relationship and Importance of Graphical Representation to Learning, 1965
- Yancey, John Mauzy, Graphical Representation of Abstract Concepts in Textual Materials, 1972

### Narrowing the Focus

An article published by Martin Rudwick in 1975 on the caricatures of De la Beche proved to be a turning point in this investigative research. Although De la Beche's texts had already been identified as unusually prolific in graphic illustration, Rudwick's article presented a different aspect of De la Beche's illustrations and artistic skills. Through the use of caricatures, De la Beche encapsulated the theoretical arguments of his day; the graphics are unusually rich in details of the historical arguments between the uniformitarians (as represented historically by Hutton, Playfair, and Lyell) and the catastrophists (as represented historically by Buckland, Sedgwick, and De la Beche). Another beautifully illustrated De la Beche book, the 1830 *Sections and Views, Illustrative of Geological Phænomena*, was located in Middleton's Circulation Shelving, and confirmed that De la Beche was unusual in his visual and educational approach to the study of geology. Therefore, the focus of the dissertation shifted to that of Henry T. De la Beche, his graphic innovations, and implications for the modern geology classroom.

### Examination of Early Geology Texts

Investigation continued, however, into graphic use by other geologic authors. Several additional texts were identified and analyzed.

**Cuvier.** Many of Cuvier's texts were located. His text on science history, written in French, offered no graphic illustrations, and was deemed of little value for this study. Likewise, Cuvier's anatomy book, although it had many illustrations, was not relevant to an investigation of early geologic texts. Cuvier and Brongniart's (1822) *Description Géologique Des Environs de Paris*, the most geologic text by Cuvier, contained 11 plates in 428 pages of text, and eight pages of advertisements and table of contents. The other Cuvier books located – the 1822 *Recherches sur les Ossements Fossiles* (five volumes, in seven books), and the 1831 translated *A Discourse on the Revolutions of the Surface of the Globe* – offered graphics of fossils, but not of geologic principles in general. Some of these illustrations had been copied from an earlier text; the 1992 copy of Cuvier's 1812 *Recherches sur les Ossements Fossils de Quadrupeds: Où l'on établit les Caractères de Plusieurs espèces d'Animaux que les Revolutions du Globe Paraissent avoir détruites Discours préliminaire* revealed three familiar ibis plates that had been copied into Cuvier's later works.

An Internet search on Cuvier appears to affirm the conclusion that he was not considered to be a geologist. Although Cuvier did seem to have laid the groundwork for vertebrate paleontology, he probably was best known for his brilliant studies in comparative anatomy.

**Von Buch.** Von Buch's (1820) *Ueber einen Vulkanischen Ausbruch auf der Insel Lanzerote* did not have any graphics.

**De Luc.** There were no illustrations in De Luc's 1831 *Letters on the Physical History of the Earth, Addressed to Professor Blumenbach: Containing Geological and Historical Proofs of the Divine Mission of Moses*. There were, however, numerous biblical references.

**Boubée.** There was only one graphic in Boubée's 1833 text, *Géologie Élémentaire, a la Portée de Tout le Monde, Appliquée a l'Agriculture et à l'Industrie*. The sole graphic, the frontispiece, was hand-colored and depicted the infilling of basins and epochs. A color key was included; the graphic was reproduced in less detail for the back cover.

**Thomson.** Thomson's (1836) *Outlines of Mineralogy, Geology, and Mineral Analysis* volumes I and II were reviewed. These texts were basic mineralogical texts. Volume I contained many line drawings of crystal shapes, while Volume II had six graphics, including an idealized section, a diagram of dikes, and four apparatus sketches.

**Humboldt.** Humboldt emerged as someone who, like Cuvier, contributed to several disciplines. Internet searches revealed that he is primarily considered a climatologist/cartographer. However, two books were located that made geological contributions. Humboldt's 1832 *Fragmente einer Geologie und Klimatologie Asiens* contained only two foldout diagrams in 272 pages of text. Plate 1 was a polar projection, and showed isotherms across the earth. This graphic contained more information than most graphics of this time. Plate 2 was a map of Asia. Humboldt also collaborated with Rose and Ehrenberg in the 1837 *Reise nach dem Ural, dem Altai und dem Kaspischen Meere auf Befehl Sr. Majestät des Kaisers von Russland im Jahre 1829*. This text contained four graphics in the text, and 10 plates. The plates represented crystallographic forms and maps. Plate 7 was missing from the text.

**D'Orbigny.** The 1839 *Mémoires de la Société Géologique de France Mémoire sur les Foraminifères de la Craie Blanche De Bassin de Paris* was found to contain several plates of line drawings of foraminifera.

**Phillips.** An 1823 text of *An Elementary Introduction to the Knowledge of Mineralogy: Comprising Some Account of the Characters and Elements of Minerals; Explanations of Terms in Common Use; Descriptions of Minerals, with Accounts of the Places and Circumstances in Which They Are Found; and Especially the Localities of British Minerals* arrived through interlibrary loan. This third, enlarged edition contained numerous line drawings of crystals, whose faces were labeled with letters. The figures were incorporated throughout the text. A few figures of apparatus and one foldout map of mineralogical apparatus were also included.

**Hutton.** Hutton's third volume of *Theory of the Earth* was published posthumously approximately 100 years after his death. The manuscript fell into the hands of Playfair after Hutton's death; however, Playfair decided not to publish it. Geikie, the editor of the 1899 printing of volume III, speculated it was perhaps due to the missing illustrations that the manuscript was not published. Geikie added his own illustrations to the text. Since the illustrations are not the original intended illustrations, this text is not important to this study.

**De la Beche.** Additional texts by De la Beche were also located, including what was supposed to be the third edition of *A Geological Manual* through Interlibrary Loan. However, this latest edition appeared to be the identical version of an 1832 edition previously reviewed.

De la Beche's 1830 *Geological Notes* was also briefly reviewed. It incorporated only two graphics. An 1876 posthumously published *Catalogue of Specimens in the Museum of Practical Geology, Illustrative of the Composition and Manufacture of British Pottery and Porcelain, from the Occupation of Britain by the Romans to the Present Time*; an 1839 *Report on the Geology of Cornwall, Devon, and West Somerset*, with 84

figures in the text and 13 plates; and the 1824 *A Selection of the Geological Memoirs Contained in the Annales Des Mines, Together with a Synoptical Table of Equivalent Formations and M. Brongniart's Table of the Classification of Mixed Rocks*, with 11 plates were also found and briefly reviewed.

### **Interlibrary Loan Requests and Cancellations**

As research continued, additional books and articles were recognized that might provide useful to this study. Many of the De la Beche books were located from web searches of the library catalogs of Cambridge University and Oxford University. Unfortunately, some of the requests could not be filled. I have been notified of several cancellations by interlibrary loan, including

- Eine korrigierte Karikatur in *Palaeontologische Zeitschrift* 50, p. 228-230, 1976
- *Abrégée de Gêologie* by Omalius d'Halloy
- *Eléments de gêologie* by Jean Julian Omalius d'Halloy
- *Recherches sur les Ossements Fossils des Quadrupeds* (4 volumes) by Cuvier
- Remarks on the Geology of Jamaica by H. T. De la Beche in *G Soc London, Tr.*
- *Memoirs of the Geological Survey of Great Britain*, 1846-1866
- *Vorschule der Geologie* by H. T. De la Beche
- *Mining, Quarrying, and Metallurgical Processes and Products* by H. T. De la Beche



- *On the Formation of the Rocks of South Wales and South Western England, Memoirs of the Geological Survey of Great Britain and of the Museum of Economic Geology in London* by H. T. De la Beche
- *First Report on the Coals Suited to the Steam Navy* by H. T. De la Beche
- *Reports on the Gases and Explosions in Collieries* by De la Beche, Lyon Playfair, and Warrington Smith
- *A Tabular and Proportional View of the Superior, Supermedial, and Medial Rocks* by H. T. De la Beche

### **Potential Interviews and Contributors**

I was able to establish contact with several people with potential contributions to this study. Dr. Martin Rudwick, a noted paleontologist and historian of geology has agreed to meet with me in England. Dr. Hugh Torrens, an historian of science and an authority on Mary Anning, has likewise agreed to an interview. Mr. Tom Sharpe, Curator of the archives at the National Museum of Wales where the De la Beche archives are housed, has offered his assistance in this project. William Brice, the editor of the Geological Society of America History of Geology newsletter has offered to include a notice in the newsletter about my current research into illustrations of early modern geologic texts.

### **Reference Books**

Additional reference material for this study has been located. *The Birth and Development of the Geological Sciences* by Adams (1938), *Giants of Geology* by Fenton and Fenton (1952), and *It Began with a Stone: A History of Geology from the Stone Age to the Age of Plate Tectonics* (1983) by Faul and Faul have been reviewed, but were found to contribute no new material. Likewise, Gillispie's *Genesis and Geology: A*

*Study in the Relations of Scientific Thought, Natural Theology, and Social Opinion in Great Britain, 1790- 1850* does not seem to contribute greatly to this study. Geikie's and Woodward's texts on the history of geology have proven much more useful, as has Sollas' 1905 text, *The Age of the Earth and Other Geological Studies*.

Articles by the late Susan Sheets-Pyenson (including *Geological Communication in the Nineteenth Century: the Ellen S. Woodward Autograph Collection at McGill University*) have hinted that there might have been changes in printing techniques during the age of focus for this study. This topic will be further investigated.

Although I located a book with the "missing drawings" from Hutton's third volume of *Theory of the Earth* (*James Hutton's Theory of the Earth: The Lost Drawings* by Craig), the drawings were not correctly identified as to their original proposed placement. Unfortunately, these graphics will not be useful in this investigation.

De la Beche is notably absent from many websites of geologists, including <http://www.nceas.ucsb.edu/~alroy/lefa/pages.html> . De la Beche was also notably absent from the list of biographies in White's (1978) *Essays on the History of Geology*.

An article by Hankins on the Internet (web address <http://www.journals.uchicago.edu/Isis/journal/demo/v000n000/000000/000000.text.html>) briefly summarized a history of graphic illustrations. Several references in the article appeared useful, and were ordered through interlibrary loan.

Interesting books arrived through interlibrary loan on De la Beche, including Sharpe and McCartney's *The Papers of H. T. De la Beche*, McCartney's *Henry De la Beche: Observations on an Observer*, and Fowles' *A Short History of Lyme Regis*. Two books authored by Rudwick, *The Great Devonian Controversy*, and *Georges Cuvier, Fossil Bones, and Geological Catastrophes* appear to offer potential insight to this study,

as does Gould's *Time's Arrow*, *Time's Cycle*. Several other prospective reference books have also been identified.

## Appendix B: Internal Review Board Form

### Application for Exemption from IRB (Institutional Review Board) Oversight for Studies Conducted in Educational Settings LSU COLLEGE OF EDUCATION

Title of Study: Uncovering Strata: An Investigation into the Graphic Innovations of Henry T. de la Beche  
Principal Investigator: Renee C. Godley

Name (print)

Faculty Supervisor: Dr. James Wandersee  
(if student project) Name (print)

Date of proposed project period: From May 2002 To May 2003

ITEM	YES	NO
1. This study will be conducted in an established or commonly accepted educational setting (schools, universities, summer programs, etc.)	X	
2. This study will involve children under the age of 18.		X
3. This study will involve educational practices such as instrumental strategies or comparison among educational techniques, curricula, or classroom management strategies.		X
4. This study will involve educational testing (cognitive, diagnostic, aptitude, achievement.)		X
5. This study will use data, documents, or records that existed prior to the study.	<del>X</del>	
6. This study will use surveys or interviews concerning content that is <u>not</u> related to instructional practices.		X
7. This study will involve procedures other than those described in numbers 3, 4, 5, or 6. If yes, describe: _____		X
8. This study will deal with sensitive subjects' and/or subjects' families lives, such as sexual behavior or use of alcohol or other drugs.		X
9. Data will be recorded so that the subjects cannot be identified by anyone other than the researcher.	X	
10. Informed consent of the subject cannot be identified by anyone other than the researcher.	X	
11. Assent of minors (under age 18) will be obtained. (Answer if #2 is above is Yes)		
12. Approval for this study will be obtained from the appropriate authority in the educational setting.	X	

Attach an abstract of the study and a copy of the consent form(s) to be used. If your answer(s) to numbers 6 and/or 7 is (are) YES, attach a copy of any surveys, interview protocols, or other procedures to be used.

- OVER -

## ASSURANCES

As the principal investigator for the proposed research study, I assure that the following conditions will be met:

1. The human subjects are volunteers.
2. Subjects know that they have the freedom to withdraw at any time.
3. The data collected will not be used for any purpose not approved by the subjects.
4. The subjects are guaranteed confidentiality.
5. The subjects will be informed beforehand as to the nature of their activity.
6. The nature of the activity will not cause any physical or psychological harm to the subjects.
7. Individual performances will not be disclosed to persons other than those involved in the research and authorized by the subject.
8. If minors are to participate in this research, valid consent will be obtained beforehand from parents or guardians.
9. All questions will be answered to the satisfaction of the subjects.
10. Volunteers will consent by signature if over the age of 6.

**Investigator Statement:**

I have read and agree to abide by the standards of the Belmont Report and the Louisiana State University policy on the use of human subjects. I will advise the Office of the Dean and the University's Human Subject Committee in writing of any significant changes in the procedures detailed above.

Signature Renee C. Godley Date 3-14-02

**Faculty Supervisor Statement (required for student research projects):**

I have read and agree to abide by the standards of the Belmont Report and the Louisiana State University policy on the use of human subjects. I will supervise the conduct of the proposed project in accordance with federal guidelines for Human Protection. I will advise the Office of the Dean and the University's Human Subject Committee in writing of any significant changes in the procedures detailed above.

Signature James H. Wandersee Date 3-18-02

**Reviewer recommendation:**

- ☒ exemption from IRB oversight. (File this signed application in the Dean's Office.)
- ☐ expedited review for minimal risk protocol. (Follow IRB regulations and submit 3 copies to the Dean's Office.)
- ☐ full review. (Follow IRB regulations and submit 13 copies to the Dean's Office.)

Name of Authorized Reviewer: Petra Munro / Petra Munro / 3/19/2002  
 Print name / Signature / Date

## **Uncovering Strata: An Investigation Into the Graphic Innovations of Geologist Henry T. De la Beche**

**Renee C. Godley**  
**Dr. James H. Wandersee**

This research study proposes to investigate the role played by Henry T. De la Beche and his geology graphics in shaping early geological thought, as well as the implications for improving geology education today. This research involves the study of the historical context in which modern geology, and its increasing dependence upon graphics, emerged. The graphic innovations of Henry T. De la Beche, and their contributions to geology and geological education, will be identified. Research will focus upon the nature and progression of early geological graphics (1788-1840), with special emphasis on Henry T. De la Beche's; analysis of geological graphics with Edward R. Tufte's theory of graphic design will reveal their strengths and weaknesses.

Research will primarily be carried out in libraries, museums, and special collections housing early geological texts. The Natural History Museum of Wales in Cardiff currently holds many papers of De la Beche. Therefore, the only subjects involved in this study are those historians of science, especially geology, who agree to be interviewed. Dr. Martin Rudwick, currently associated with Cambridge University and a noted specialist on the history of geology, has kindly agreed to meet with the researcher this summer in England.

Since this research project is an historical study, only those people knowledgeable in the history of science are potential contributors. History of science specialists, particularly those with geological subspecialties, may be identified through their published works as the study progresses. Dr. Martin Rudwick, who has published numerous studies in history of geology,

may also identify additional people who will be able to provide information via interviews. These people will be contacted via mail or e-mail requesting their assistance in this project.

Interviews will be conducted in times and places jointly arranged by the researcher and the subject. If logistics present great difficulty, the subject will be asked to consent to a telephone interview. All subjects will be given a personal copy of the consent form prior to the interview, which will explain the study and assure confidentiality if the subject so desires. Questions concerning the interview will be answered prior to the signing of the form. Interview protocol will follow a general interview guide (Patton, 1990). Specific questions concerning the emergence of geology as a science (1788-1840), the emergence of graphics within the field, and principal contributors to the science, especially Henry T. De la Beche, will be enumerated on the interview guide. These questions will not be the only questions asked, however; the responses and the situations of the subjects will determine follow-up questions as well as tangential topics to be explored in the interview. Tape recordings will be made if the subject grants permission, and the researcher will also take notes during the session. Tapes will be transcribed, and analyzed for content.

If the subject desires confidentiality, the researcher will not identify the subject in the research either by name or discerning information. Subjects will not be identified on the tapes, or within the notes, except by pseudonym. The consent forms, notes, and tapes will be housed in a locked filing cabinet in the researcher's office at the University of Louisiana at Lafayette.

Early geological texts, especially the texts of Henry T. De la Beche, will be located via Interlibrary Loan if possible. Those texts that are non-circulating will be examined within the library or museum that houses them. The researcher will seek permission from the proper authorities at each institution to examine the important texts, as well as to scan or digitally

photograph graphics within the texts. Elaine Smyth, LSU Curator of Rare Books and the E. A. McIlhenny Natural History Collection, will be asked to provide assistance and serve as the liaison for some of these special collections. The emerging graphics in the early geological field (1788 – 1840), especially those of Henry T. De la Beche, will be analyzed using Edward R. Tufte's theory of graphic design. Interviews with historians of science will be conducted to add to the researcher's understanding of the graphics and the geological field during the period in question (1788-1840).

After the interviews, subjects will be asked if they have any questions that need clarification regarding the interview, its potential uses, and confidentiality. Subjects will also be offered the opportunity to proofread the transcript of the interview after it is completed. No potential risks to the subjects have been identified.

Sources:

Patton, M. (1990) *Qualitative evaluation and research methods*. Newbury Park, CA: Sage Publications.



## Uncovering Strata: An Investigation Into the Graphic Innovations of Geologist Henry T. De la Beche

### Renee C. Godley

16 Duperier Oaks Drive  
New Iberia, LA 70563

[rgodley@cox-internet.com](mailto:rgodley@cox-internet.com)

Home: 337-364-6218 (evenings after 6 PM)

Office: 337-482-1166 (M – W – F, 1 – 3 PM)

Cell: 337-519-9224

### Dr. James H. Wandersee

Professor, Co-Director of the 15 Degree Laboratory  
223F Peabody Hall

Louisiana State University

Baton Rouge, LA 70803

[jwander@lsu.edu](mailto:jwander@lsu.edu)

Campus phone: 225-578-2348 (F, 7:30 AM – 5 PM)

Fax: 225-766-3019

### Consent Form

Thank you for participating in this study! The subject of this research is the investigation of the role of Henry T. De la Beche and his geology graphics in shaping early geological thought, and the implications to be drawn from these graphics for improving geology education today. This research involves the study of the historical context in which modern geology, and its increasing dependence upon graphics, emerged. The graphic innovations of Henry T. De la Beche, and their contributions to geology and geological education, will be identified. Research will focus upon the nature and progression of early geological graphics (1788 – 1840), with special emphasis on Henry T. De la Beche's; analysis of geological graphics with Edward R. Tufte's theory of graphic design will reveal their strengths and weaknesses. This study is being conducted as part of my dissertation research for the degree of Ph.D. in Curriculum and Instruction, Science Education, at Louisiana State University.

Your involvement in this study will be in the form of an interview. You will be asked questions about your knowledge of the history of geology, particularly early geological graphics. Questions probing your knowledge of Henry T. De la Beche and his contemporaries will also be asked. Notes will be taken during the interview. Additionally, a tape recorder will be used in order to verify and clarify the notes taken. If at any time you do not wish to discuss something on tape, please let me know. I will happy to turn off the tape recorder while you make a statement "off the record." You will be given the opportunity to review a transcript of your interview if you so desire.

No risks to you, by your participation in this study, have been identified. By participating in this study, you will help to uncover the role of early geology graphics, and in particular, the role of Henry T. De la Beche.

Your participation is entirely voluntary and you may withdraw consent and terminate participation at any time without consequence.

If you desire, your identity will be fully protected in this study. You will not be identified by name, and you will be given a pseudonym. If your statements are later quoted, you will not be identified by name or discerning information. The tapes, notes, and consent forms will be stored in a locked filing cabinet in my office at University of Louisiana at Lafayette. It is anticipated that the final dissertation will be submitted in May 2003. It will be available on-line through Louisiana State University if you wish to review it.

If you have any questions or concerns, please feel free to contact me.

*"I have been fully informed of the above-described procedure, its possible benefits and risks, and I give my permission in the study."*

\_\_\_\_\_  
Subject Name

\_\_\_\_\_  
Date

*"I do not require confidentiality. I hereby give my permission to be quoted by name in the study."*

\_\_\_\_\_  
Subject Name

\_\_\_\_\_  
Date

## Appendix C: Letters of Introduction and Support



LOUISIANA STATE UNIVERSITY  
AND AGRICULTURAL AND MECHANICAL COLLEGE  
Department of Curriculum and Instruction

12 June 2002

To British Library Officials:

This letter is to introduce Ms. Renee Godley who is a Ph.D. candidate at Louisiana State University and a member of my visual cognition research group in science education there. I am a current card-holder of the British Library and I am directing her research project at Louisiana State University, which is classified as a Carnegie Research I. (doctoral extensive) university and enrolls approximately 31,000 students.

I respectfully request that Ms. Godley be permitted to use the British Library to pursue her research on Henry de la Beche, his peers, and the Golden Age of British Geology, with regard to the types graphic representation of scientific knowledge being employed. Ms. Godley has already traveled to and examined the resources of the other principal libraries in the US and the UK in her scholarly pursuit of this subject and she has determined that the British Library holds specific books and reference materials that she can access nowhere else in the world.

Ms. Godley holds a master's degree in geology and she has successfully written and defended her 200-page science education research prospectus before a committee of four LSU graduate faculty members. In addition, she has been trained in the careful handling of rare books by the Louisiana State University Special Collections Librarian. I can assure you that she is an advanced, bona fide scholar. She will follow all the rules of your institution, and will treat your collection with the utmost care.

Respectfully,

James H. Wandersee, Ph.D.  
The William LeBlanc Alumni Professor and Fellow of AAAS  
Faculty of Science Education  
Louisiana State University  
Baton Rouge, Louisiana 70803 USA



## Department of Geology

P.O. Box 44530  
Lafayette, LA 70504-4530  
Office: (337) 482-6468  
Fax: (337) 482-6688  
E-mail: [geology@louisiana.edu](mailto:geology@louisiana.edu)

*Université des Acadiens*

Sheila Meredith  
Chief Librarian  
The Geological Society  
Burlington House  
Piccadilly  
London W1J 0BG  
ENGLAND

May 23, 2002

**Re: Ms Renee Godley**

Dear Ms. Meredith,

This is to introduce Ms. Godley to you and to request that you give her cooperation with her dissertation research. Renee is an old friend of mine, originally my student while engaged in her M.S. degree in Geology at the University of Louisiana. She is now in the Ph.D. program at Louisiana State University and I have followed details of her research project in the History of Geology with considerable interest. She is a serious and gifted researcher and absolutely to be trusted to treat any library materials with care and respect. I would request that you allow her access to the documents she requires, with my guarantee of her character.

Please feel free to address any questions to me by e-mail at [belock@louisiana.edu](mailto:belock@louisiana.edu) and I will reply quickly.

Yours Sincerely,

Brian E. Lock, Ph.D., F.G.S.  
Professor and Head of Geology  
University of Louisiana at Lafayette  
Fellowship number: 1007653





## Department of Geology

P.O. Box 44530  
Lafayette, LA 70504-4530  
Office: (337) 482-6468  
Fax: (337) 482-6688  
E-mail: [geology@louisiana.edu](mailto:geology@louisiana.edu)

*Université des Acadiens*

Andrew Mussell  
Chief Archivist  
The Geological Society  
Burlington House  
Piccadilly  
London W1J 0BG  
ENGLAND

May 23, 2002

**Re: Ms Renee Godley**

Dear Ms. Meredith,

This is to introduce Ms. Godley to you and to request that you give her cooperation with her dissertation research. Renee is an old friend of mine, originally my student while engaged in her M.S. degree in Geology at the University of Louisiana. She is now in the Ph.D. program at Louisiana State University and I have followed details of her research project in the History of Geology with considerable interest. She is a serious and gifted researcher and absolutely to be trusted to treat any library materials with care and respect. I would request that you allow her access to the documents she requires, with my guarantee of her character.

Please feel free to address any questions to me by e-mail at [belock@louisiana.edu](mailto:belock@louisiana.edu) and I will reply quickly.

Yours Sincerely,

Brian E. Lock, Ph.D., F.G.S.  
Professor and Head of Geology  
University of Louisiana at Lafayette  
Fellowship number: 1007653





LOUISIANA STATE UNIVERSITY  
AND AGRICULTURAL AND MECHANICAL COLLEGE  
LSU Libraries · Special Collections

May 2, 2002

To Whom It May Concern:

I am writing this letter on behalf of Ms. Renee Godley, a graduate student at Louisiana State University. Ms. Godley has used our Special Collections library and is a reader in good standing. She has demonstrated knowledgeable care in handling antiquarian books and a respect for them, as well as for the library's rules and regulations. In addition, I have had several interviews with Ms. Godley regarding her research and I can attest to the seriousness of her scholarly endeavor and her intellectual integrity.

I hope that you and your institution will be able to assist her in her research, as I believe she deserves such assistance. If you have any questions, please contact me by email ([esmyth@lsu.edu](mailto:esmyth@lsu.edu)), as I on leave from the library and traveling in Europe May 4 - July 28.

Sincerely yours,

Elaine B. Smyth  
Curator, Special Collections  
225/578-6547  
[esmyth@lsu.edu](mailto:esmyth@lsu.edu)





LOUISIANA STATE UNIVERSITY  
AND AGRICULTURAL AND MECHANICAL COLLEGE  
LSU Libraries · Special Collections

May 2, 2002

Mr. Tom Sharpe  
Curator, Palaeontology and Archives  
Department of Geology  
National Museum of Wales  
Cathays Park, Cardiff  
Wales CF10 3NP  
United Kingdom

Dear Mr. Sharpe,

I am writing to you on behalf of Ms. Renee Godley, a graduate student at Louisiana State University. Ms. Godley has used our Special Collections library and is a reader in good standing. She has demonstrated knowledgeable care in handling antiquarian books and a respect for them, as well as for the library's rules and regulations. In addition, I have had several interviews with Ms. Godley regarding her research and I can attest to the seriousness of her scholarly endeavor and her intellectual integrity.

I hope that you and your institution will be able to assist her in her research, as I believe she deserves such assistance. If you have any questions, please contact me by email ([esmyth@lsu.edu](mailto:esmyth@lsu.edu)), as I on leave from the library and traveling in Europe May 4 - July 28.

Sincerely yours,

Elaine B. Smyth  
Curator, Special Collections  
225/578-6547  
[esmyth@lsu.edu](mailto:esmyth@lsu.edu)

**R. Godley**

**From:** "Prof. M.J.S. Rudwick" <mjsr100@cus.cam.ac.uk> To: "R. Godley" <rgodley@cox-internet.com> **Sent:** Sunday, February 10, 2002 10:10 AM  
**Subject:** Re: A special thank you, and an introduction

Dear Renee Godley -I look forward to talking over these topics in due course. You have a fine subject! I suppose you know De la Beche's "Sections and Views" 1830- a remarkably innovative work visually, I think. I went to Cardiff a month ago to look (again) at his MSS in the National museum of Wales, and saw in his journals some of the original sketches for that book and other works. You should make time to go there while you're in Britain (if you haven't already arranged to do so). I leave it you or Brian to let me know your dates, so that we can fix a meeting. Meanwhile, good luck with your research! -Martin rudwick

**R. Godley**

From: <Tom.Sharpe@nmgw.ac.uk> To: <rgodley@cox-internet.com>  
Sent: Wednesday, February 06, 2002 8:22 AM Subject: De la Beche

Dear Renee

Your enquiry via our website has been forwarded to me. I would be happy to help in any way I can with your dissertation on early geological illustrations.

Best wishes

Tom Sharpe,  
Curator, Palaeontology and Archives, Department of Geology ,  
National Museum of Wales, Cathays Park, Cardiff, Wales  
CF103NP  
tel +44 (0) 29 2057 3265  
fax +44 (0) 29 2066 7332



## Appendix D: Book and Publication Research List for the United Kingdom

AUBUISSON DE VOISINS. Jean Francois d'  
Traité de géognosie  
2 tom. Strasbourg, 1819. 8o

AUBUISSON DE VOISINS. Jean Francois d'  
Traité de géognosie  
Nouvelle édition,. revue, etc. [Continued by A. Burat.]  
3 tom. Paris, 1828-35. 8o

BOASE, HENRY SAMUEL  
A Treatise on Primary Geology, etc.  
pp. xi. 399. Longmans & Co.: London, 1834. 8o

BREISLAK. Scipione  
[Institutions géologiques.] Traité sur la structure extérieure du globe, ou Institutions  
géologiques ... Avec un atlas de 56 planches.  
4 pt. Milan, 1822. 8o & obl. fol.

BREISLAK. Scipione  
Introduzione alla geologia  
2 pt. Milano, 1811. 8o.

CHENEVIX, Richard  
Observations on Mineralogical Systems. . . Translated from the French, by a member of  
the Geological Society. To which are now added, Remarks of Mr. Chenevix on the reply  
of M. D'Aubuisson to the above Observations.  
AUBUISSON DE VOISINS. Jean Francois d'  
pp. viii 138. J. Johnson & Co.  
London, 1811, 8o.

DE LA BECHE, Sir. Henry Thomas.  
On the depth and temperature, etc. Sur la profondeur et la temperature du lac de Genève.  
Lettre addressée au Prof. Pictet par Mr H. T. De la Beche. *Bibliothèque Universelle*, Vol.  
12, pp. 118-126.  
1819

DE LA BECHE, Sir. Henry Thomas  
On the depth and temperature of the Lake of Geneva. Communicated by Professor Pictet.  
With a map. *Edinburgh Philosophical Journal*, Vol. 2 no. 3, 1820, pp. 106-110.  
1820

DE LA BECHE, Sir. Henry Thomas

Température de quelques lacs de la Suisse, *Annalen der Physik. L. W. Gilbert*, Vol. 14, pp. 144-145

1820

DE LA BECHE, Sir. Henry Thomas

Sur la température des lacs de Thun et de Zug, en Suisse. *Bibliothèque Universelle*, Vol. 14, pp. 144-145.

1821

DE LA BECHE, Sir. Henry Thomas

Température de quelques lacs de la Suisse. *Annals de Chimie*, Vol. 19, pp. 77-83

1821

DE LA BECHE, Sir. Henry Thomas

With Conybeare. . . Notice of the discovery of a new fossil animal, forming a link between the Ichthyosaurus and crocodile; together with general remarks on the osteology of the Ichthyosaurus [read 6 Apr 1821]. *Transactions of the Geological Society of London*, First Series, Vol. 5, part 2, pp. 559-594.

1821

DE LA BECHE, Sir. Henry Thomas

Remarks on the geology of the south coast of England, from Bridport Harbour, Dorset, to Babbacombe Bay, Devon [read 5 Mar 1819]. *Transactions of the Geological Society of London*, Second Series, Vol. 1, part 1, pp. 40-47. *Isis*, Vol. 12 (1823) pp. 180-181

1822

DE LA BECHE, Sir. Henry Thomas

Notice respecting fossil plants found at Col de Balme, near Chamouny in Savoy [read 3 Nov 1820]. *Transactions of the Geological Society of London*, Second Series, Vol. 1, part 1, pp. 162-163.

1822

DE LA BECHE, Sir. Henry Thomas

On the geology of the coast of France, and of the inland country adjoining; from Fécamp, Department de la Seine Inferieure, to St Vaast, Department de la Manche [read 2 Nov 1821]. *Transactions of the Geological Society of London*, Second Series, Vol. 1, part 1, pp. 73-89.

1822

DE LA BECHE, Sir. Henry Thomas

Versuche über das Frieren mit Oel bedeckten Wassers. *Annalen der Physik. L. W. Gilbert*, Vol. 71, pp. 435-436.

1822

DE LA BECHE, Sir. Henry Thomas

*Map of 24 miles around the city of Bath. . .by C. Harcourt Masters, coloured geologically by Rev. W. D. Conybeare and H. T. De la Beche.* Bath.

1823

DE LA BECHE, Sir. Henry Thomas

Notice of the discovery of a large fossil elephant's tusk, near Charmouth, Dorset. [read 2 May 1823] *Transactions of the Geological Society of London*, Second Series, Vol. 1, part 2, pp. 421-422.

1824

DE LA BECHE, Sir. Henry Thomas

Catalogue of the birds, and of the terrestrial and fluviatile molluscae, found in the vicinity of Geneva. *Zoological Journal*, Vol. 1, no. 1, pp. 89-93

1824

DE LA BECHE, Sir. Henry Thomas

A selection of the geological memoirs, contained in the *Annales des mines*

London: William Phillips

1824

DE LA BECHE, Sir. Henry Thomas

Notice on the temperature of the surface water of the Atlantic, observed during a voyage to and from Jamaica. *Annals of Philosophy*, New Series, Vol. 10, pp. 333-335.

1825

DE LA BECHE, Sir. Henry Thomas

Notes on the Present Condition of the Negroes in Jamaica.

pp. 63. T. Cadell: London, 1825. 8o.

DE LA BECHE, Sir. Henry Thomas

Notes on the Diluvium of Jamaica. *Annals of Philosophy*, New Series, Vol. 10, pp. 54-58

1825

DE LA BECHE, Sir. Henry Thomas

On the Lias of the coast in the vicinity of Lyme Regis, Dorset [read 21 Nov 1823]

*Transactions of the Geological Society of London*, Second Series, Vol. 2, part 1, pp. 1-20.

1826

DE LA BECHE, Sir. Henry Thomas

On the geology of southern Permbrookeshire [read 16 May 1823]. *Transactions of the Geological Society of London*, Second Series, Vol. 2, part 1, pp. 21-30.

1826

DE LA BECHE, Sir. Henry Thomas

On the Chalk and sands beneath it (usually termed Green-sand) in the vicinity of Lyme Regis, Dorset and Beer, Devon [read 16 December 1825]. *Transactions of the Geological Society of London*, Second Series, Vol. 2, part 1, pp. 109-118.

1826

DE LA BECHE, Sir. Henry Thomas

Notice of traces of a submarine forest at Charmouth, Dorset. *Annals of Philosophy*, New Series, Vol. 11, p. 143

1826

DE LA BECHE, Sir. Henry Thomas

*Carte des principales Sondes du lac Léman*. Genève: Briquet et Dubois.

1827

DE LA BECHE, Sir. Henry Thomas

Remarks on the geology of Jamaica [read 2 Dec 1825 and 6 Jan 1826]. *Transactions of the Geological Society of London*, Second series, Vol. 2, part 2, pp. 143-194.

1827

DE LA BECHE, Sir. Henry Thomas

A tabular and proportional view of the superior, supermedial and medial rocks: (Tertiary and secondary rocks)

London: W. Phillips, 64 pp. (2nd ed. 1828)

1827

DE LA BECHE, Sir. Henry Thomas

Nummulites in the Greensand Formation. *Philosophical Magazine*, New Series, Vol. 4, p. 235.

1827

DE LA BECHE, Sir. Henry Thomas

On the geology of Tor and Babbacombe Bays, Devon [abstract] *Proceedings of the Geological Society of London*, Vol. 1, no. 4 (1827-28), pp. 31-33

1828

DE LA BECHE, Sir. Henry Thomas

Notes on the habits of a Caryophyllia from Tor Bay, Devon. *Zoological Journal*, Vol. 3, no. 12, pp. 481-486. *Isis*, Vol. 23 (1830), pp. 1238-1239. *Heusinger's Zeitschrift für die organische Physik*, Vol. 3, pp. 90-93.

DE LA BECHE, Sir. Henry Thomas

On the geology of Nice [abstract]. *Proceedings of the Geological Society of London*, Vol. 1, no. 9 (1828-29), pp. 87-89

1829

DE LA BECHE, Sir. Henry Thomas

On the geology of Tor and Babbacombe Bays, Devon [read 16 Nov 1827]. *Transactions of the Geological Society of London*, Second Series, Vol. 3, part 1, pp. 161-170  
1829

DE LA BECHE, Sir. Henry Thomas

On the geology of the shores of the Gulf of La Spezia [abstract] *Proceedings of the Geological Society of London*, Vol. 1, no. 14 (1829-39) pp. 164-167  
1829

DE LA BECHE, Sir. Henry Thomas

Note on the differences, either original or consequent on disturbance, which are observable in the Secondary Stratified rocks. *Philosophical Magazine New Series*, Vol. 6. pp. 213-215. *Annales des Sciences Naturelle*, Vol. 17, pp. 427-445.  
1829

DE LA BECHE, Sir. Henry Thomas

Notice on the excavation of valleys. *Philosophical Magazine and Annals of Philosophy*, New Series, Vol. 6. pp. 241-248.  
1829

DE LA BECHE, Sir. Henry Thomas

Sketch of a classification of the European rocks. *Philosophical Magazine, New Series*, Vol. 6, p. 440. *American Journal of Science*, 1830, vol. 18, p. 26. *Bulletin Universel des Sciences et d'Industrie (2e section)*. *Bulletin des Sciences Naturelles et de Géologie*, 1830, Vol. 20, pp. 17-19.  
1829

DE LA BECHE, Sir. Henry Thomas

On the geographical distribution of organic remains contained in the Oolitic series of the great London and Paris Basins, and in the same series of the south of France. *Philosophical Magazine, New Series*, Vol. 7, pp. 81-95, 202-205, 250-268, 334-351; Vol. 8, pp. 35-44, 208-213, *Bulletin Universel des Sciences et d'Industrie (2e section)*. *Bulletin des Sciences Naturelles et de Géologie*, vol. 23, pp. 191-200.  
1830

DE LA BECHE, Sir. Henry Thomas

On the formation of extensive conglomerate and gravel deposits *Philosophical Magazine, New Series*, Vol. 7, pp. 161-171. *Bulletin Universel des Sciences et d'Industrie (2e section)*. *Bulletin des Sciences Naturelles et de Géologie*, vol. 22, pp. 164-165.  
1830

DE LA BECHE, Sir. Henry Thomas

With W. Buckland. On the geology of Weymouth and the adjacent parts of the coast of Dorsetshire [abstract] *Proceedings of the Geological Society of London*, Vol. 1, no. 16 (1829-30), pp. 217-221  
1830

DE LA BECHE, Sir. Henry Thomas.  
A Geological Manual  
Third edition, considerably enlarged.  
pp. ix. 629. Charles Knight: London, 1833. 8o.

DE LA BECHE, Sir. Henry Thomas  
Sur les environs de La spezia. *Mémoires de la Société géologique de Paris*, Vol. 1, pp. 23-36.  
1833

DE LA BECHE, Sir. Henry Thomas  
On the anthracite found near Bideford in north Devon. *Proceedings of the Geological Society of London*. Vol. 2, no. 37, pp. 106-107  
1834

DE LA BECHE, Sir. Henry Thomas  
Lettre sur la découverte d'empreintes de plantes dans les Schists Subordonnés à la formation de la Grauwacke. *Bulletin de la Société géologique de France*, Vol. 6, p. 90  
1835

DE LA BECHE, Sir. Henry Thomas  
Note on the Trappean rocks associated with the (New) Red Sandstone of Devonshire *Proceedings of the Geological Society of London*, Vol. 2, no. 41, pp. 196-198.  
1835

DE LA BECHE, Sir. Henry Thomas  
With W. Buckland. On the geology of the neighbourhood of Weymouth and the adjacent parts of the coast of Dorset. [read Apr 2 and 16, 1830]. *Transactions of the Geological Society of London*, Second series, Vol. 4, part 1, pp. 1-46.  
1835

DE LA BECHE, Sir. Henry Thomas  
[Notice of fossils from the schistose rocks of North Cornwall] *Proceedings of the Geological Society of London*, Second Series, Vol 2, no. 43 (1835-36), pp. 225-226.  
1836

DE LA BECHE, Sir. Henry Thomas  
*Untersuchungen über theoretische Geologie*. Translated by C. Hartmann.  
1836

DE LA BECHE, Sir. Henry Thomas  
*Anteilung zum wissenschaftl. Beobachten. I. Geologie*. Berlin  
1836

DE LA BECHE, Sir. Henry Thomas  
*Manuel géologique*. 2<sup>nd</sup> edition. Translated into French by A.J. M. Brochant de Villiers.  
Brussels: Meline, xxxvi + 506 pp.  
1837

DE LA BECHE, Sir. Henry Thomas.

On certain phenomena connected with the metalliferous veins of Cornwall: Report of the British Association for the Advancement of Science (6<sup>th</sup>), Transactions of the sections (Geology), p. 83-84

1837

DE LA BECHE, Sir. Henry Thomas

*L'Art d'observer en géologie.* Translated by H. de Collegno. Paris: Levraut, vii + 232 pp.

1838

DE LA BECHE, Sir. Henry Thomas

*Coupes et vues pour servir à l'explication des phénomènes géologiques.* Translated by H. De Collegno.

1839

DE LA BECHE, Sir. Henry Thomas

On the influence of atmospheric pressure on the tidal waters of Cornwall and Devon.

*Edinburgh New Philosophical Journal* Vol. 26, pp. 415-419.

1839

DE LA BECHE, Sir. Henry Thomas

(with JC. Barry, W. Smith and C. H. Smith) Report with reference to the selection of stone for building the new Houses of Parliament. In *Parliamentary Papers for 1839* vol 30. London

1839

DE LA BECHE, Sir. Henry Thomas

On the connection between geology and agriculture in Cornwall, Devon and West Somerset. *Journal of the Agricultural Society of England*, vol. 3, pp. 21-35.

1842

DE LA BECHE, Sir. Henry Thomas

On estuaries and their tides. *Philosophical Magazine*, vol. 24, pp. 485-491. *Transactions of the Royal Geological Society of Cornwall*, Vol. 6, 1846, pp. 211-218.

1844?

DE LA BECHE, Sir. Henry Thomas

Report of the Commissioners appointed to inquire into the facts relating to the ordnance memoir of Ireland: together with the minutes of evidence, appendix, and index

London: HMSO, 1877

DE LA BECHE, Sir. Henry Thomas

First report of the Commissioners for inquiring into the state of large towns and populous districts/Commissioners for Inquiring into the State of large towns and populous districts/Commissioners for Inquiring into the State of Large Towns and Populous Districts

London: HMSO, 1844

DE LA BECHE. Sir. Henry Thomas.  
 Report on the State of Bristol and other Large Towns  
 ENGLAND. Departments of State and Official Bodies. Commissioners for inquiring into  
 the State of Large Towns and Populous Districts.  
 London, 1845. 8o.

DE LA BECHE., Sir Henry Thomas.  
 On the Formation of Rocks of South Wales and South Western England.  
 B. S.38.Ga/1.(1.)  
 In: Memoirs of the Geological Survey of Great Britain, etc. vol. 1. pp. 1-296.  
 1846. 8o.

DE LA BECHE, Sir. Henry Thomas  
 With Lyon Playfair. Gases and explosions in collieries. *Journal of the Franklin Institute  
 of the State of Pennsylvania*, Vol. 13, pp. 347-353, 427-433.  
 1847

DE LA BECHE, Sir. Henry Thomas  
 Collieries. Report on the gases and explosions in collieries, by Sir Henry T. de la Beche,  
 Dr. Lyon Playfair, and Mr. Warrington Smyth. Presented to both Houses of Parliament,  
 etc.  
 PLAYFAIR, Lyon. Baron Playfair  
 SMYTH, Sir. Warrington Wilkinson  
 {Irish University Press series of British Parliamentary papers. Mining accidents. No. 6.)  
 [Shannon Irish University Press, 1969]. SGN 716508664 pp. 68: plates, maps, plans. 34  
 cm.  
 B.S. Ref. 18/19  
 A facsimile of the edition of 1847.]

DE LA BECHE, Sir. Henry Thomas  
 Anniversary address of the President. *Proceedings of the Geological Society*, Vol. 4, pp.  
 xxi-cxx.  
 1848

DE LA BECHE, Sir. Henry Thomas  
 Anniversary address of the President. *Proceedings of the Geological Society*, Vol. 5, pp.  
 xix-cxvi.  
 1849

DE LA BECHE, Sir. Henry Thomas  
 Geological changes from the Earth's axis of rotation. *Edinburgh New Philosophical  
 Journal*, Vol. 47, pp. 98-104  
 1849



DE LA BECHE, Sir. Henry Thomas

Flora of the Silurian System. Plants of the anthracite formation. Geological climate. Co-existence of Saurian and Molluscos forms. Phosphate of lime in the mineral kingdom.

*Edinburgh New Philosophical Journal*, Vol. 47, pp. 122-132

1849

DE LA BECHE, Sir. Henry Thomas

Mineralogy

In Herschel (Sir John F. W. ) Bart. A Manual of Scientific Enquiry; prepared for the use of Her Majesty's Navy; and adapted for travelers in general. London: John Murray Pp. 224-267.

1849 8o.

DE LA BECHE, Sir. Henry Thomas

With Lyon Playfair. *Second report on the coals suited to the steam navy*. Museum of Practical Geology, H.M.S.O., 57 pp.

1849

DE LA BECHE, Sir. Henry Thomas

Minutes of evidence in *A Select Committee to enquire into the best means of preventing the occurrence of dangerous accidents in mines*. London, pp. 3-24.

1849

DE LA BECHE, Sir. Henry Thomas

With Lyon Playfair. *Third report on the coals suited to the steam navy*. Museum of Practical Geology, H.M.S.O. 55 pp.

1851

DE LA BECHE, Sir. Henry Thomas

Analysis of coal from Van Diemen's Land. *Papers and Proceedings of the Royal Society of Van Diemen's Land*, Vol. 1, pp. 265-267.

1851

DE LA BECHE, Sir. Henry Thomas

Inaugural discourse, delivered at the opening of the School of Mines and of Science Applied to the Arts, 6 Nov 1851 *Records of the School of Mines and of Science Applied to the Arts*, Vol. 1, part 1 (1852), pp. 1-22.

1851

DE LA BECHE, Sir. Henry Thomas

Mining, quarrying and metallurgical processes and products. Lecture 1, December 2<sup>nd</sup> 1851 [Lecture to the Society of Arts, Manufactures etc.] pp. 17-34

1851

DE LA BECHE. Sir Henry Thomas  
Mining, Quarrying, and Metallurgical Processes and Products  
In: Lectures on the Results of the Great Exhibition of 1851, delivered before the Society of Arts, Manufactures, and Commerce, etc. ser. 1.  
pp. 35-73.  
1852. 8o.

DE LA BECHE, Sir. Henry Thomas  
*Vorschule der geologie . . . frei mit Zusätzen bearbeitet von Dr Ernst Dieffenback.*  
Brunswick: Vieweg, xviii + 624 pp  
1853

DE LA BECHE, Sir. Henry Thomas  
Note on the Stigmara beds of the South Staffordshire coal field. *Records of the School on Mines*, vol. 1, pp. 336-339.  
1853

DE LA BECHE, Sir Henry Thomas  
Museum of Practical Geology. Catalogue of specimens illustrative of the composition and manufacture of British Pottery and Porcelain from the occupation of Britain by the Romans to the present time.  
ENGLAND. Departments of State and Official Bodies. Geological Survey of the United Kingdom. Museum of Practical Geology  
DE LA BECHE, Sir. Henry Thomas. And REEKS (Trenham)  
pp. xxiii 179. London, 1855. 8o.

DELUC, Jean Andre  
An elementary treatise on Geology: determining fundamental points in that science, etc./Translated from the French Manuscript by H. De la Fite.  
London, 1809

GIRARDIN. Jean Pierre Louis. and LECOQ (H.) LECOQ, Henri  
Éléments de Minéralogie appliquée aux Sciences Chimiques. Ouvrage basé sur la méthode de. M. Berzelius ... Suivi d'un précis élémentaire de geognosie. Par J. G. et H. L.  
2 tom. Paris, 1826. 8o.  
Haëuy, Renâe Just,  
Traitâe de minâeralogie,  
Paris, 1801

LECOQ, Henri  
Éléments de géologie et d'hydrographie ... faisant suite et servant de complément aux Éléments de géographie physique et de météorologie; avec huit planches gravées.  
2 tom. Paris, Londres, Clermont-Ferrand [printed], 1838. 8o.

MACGILLIVRAY, WILLIAM  
A Manual of Geology  
London, 1840. 12o.

MANTELL, GIDEON ALGERNON

The Fossils of the South Downs; or, Illustrations of the Geology of Sussex.(illus by Mrs. Mantell)

London, 1822. 4o.

MANTELL, GIDEON ALGERNON

Thoughts on a Pebble; or a First Lesson in Geology

In. Thoughts. Thoughts, etc. 1836. 12o.

MANTELL, GIDEON ALGERNON

The Wonders of Geology; or, a familiar exposition of geological phenomena: being the substance of a course of lectures ... by G. M. ... from notes taken by G. F. Richardson.

2 vol. London, 1838. 8o.

MACCULLOCH, JOHN

A geological classification of rocks, with descriptive synopses of the species and varieties. comprising the elements of practical geology

London. Longman, Hurst, Rees, Orme and Brown .... 1821

MAWE, JOHN

Familiar Lessons on Mineralogy and Geology: with colored plates ... Seventh edition.

pp. vi. 110. Longman, Hurst, Rees, Orme, Browne, & Green; J. Mawe: London, 1825. 12o.

NAUMANN. Carl Friedrich.

Lehrbuch der Geognosie

2 Bde. Leipzig, 1840-54 8o.

OMALIUS D'HALLOY. Jean Baptiste Julien d'

Éléments de Géologie

Paris and Strasbourg, 1831. 8o

OMALIUS D'HALLOY. Jean Baptiste Julien d'

Introduction à la Géologie, ou première partie des Éléments d'histoire naturelle inorganique, contenant des notions d'astronomie, de météorologie et de minéralogie, avec un atlas de 3 tableaux et 17 planches.

Paris, 1833, 1834. 8o. & 4o.

PHILLIPS, JOHN

A guide to geology ... Second edition.

London: Longman, Rees, Orme, Brown, Green, & Longman, 1835

PHILLIPS, WILLIAM

An outline of mineralogy and geology, & c.

London 1815

SUTCLIFFE, JOSEPH

A short introduction to the study of Geology; comprising a new theory of the elevation of the mountains and the stratification of the earth: in which the Mosaic account of the Creation and the Deluge is vindicated. (Appendix.)

2 pt. London, 1817-19. 8o.

URE, ANDREW

A New System of Geology, in which the great revolutions of the earth and animated nature are reconciled at once to modern science and sacred history.

London, 1829. 8o.

## Appendix E: Lists of Archival Documents Viewed at the National Museum of Wales, British Geological Survey, and Geological Society of London

### De la Beche Collection, National Museum of Wales

Archives 144: Letter from Buckland, May 1816; sketch of fossil trees

Archives 163: Letter from W. Buckland, 20 April 1822; plesiosaurus discussion

Archives 173: Letter from Buckland, 7 July 1825; Very rough sketch of seal.

Archives 175: Letter from Buckland, 4 Feb. 1826; Offering DLB Office of Secretary

Archives 177: Letter from W. Buckland, 26 July 1829; Change of DLB's views on diluvium

Archives 180: Letter from Buckland, 1 May 1831; Mary Anning's ichthyosaurus

Archives 183: Letter from Buckland, 14 October 1831; German parody of DLB's *Duria Antiquior*

Archives 297: Letter from Conybeare, 16 December 1821; 6 sketches of ichthyosaur

Archives 299: Letter from Conybeare, 1832, 5 sketches

Archives 302: Letter from Conybeare, 4 March 1824; plesiosaurus sketches

Archives 309: Letter from Conybeare, 4 August 1834; comments on Greenough's speech

Archives 341: Pocket journal of H. T. De la Beche

Archives 342: Pocket journal of H. T. De la Beche

Archives 343: Journal of H. T. De la Beche

Archives 344: Pocket Journal of H. T. De la Beche

Archives: 345: Journal of H. T. De la Beche

Archives 346: Diary of H. T. De la Beche

Archives 347: Pocket journal of H. T. De la Beche

Archives 348: Field book of H. T. De la Beche

- Archives 349: Pocket Journal of H. T. De la Beche
- Archives 350: Pocket journal of H. T. De la Beche
- Archives 352: Diary of H. T. De la Beche
- Archives 353: Extended Jamaica Journal of H. T. De la Beche
- Archives 355: Letter from De la Beche to Conybeare, 6 March 1824; mentions translations of *Annales des Mines*
- Archives 356: Letter from De la Beche to Conybeare, April 6, 1824; sections
- Archives 357: Letter from De la Beche to Conybeare, May 13, 1824; landscape section
- Archives 361: Manuscript No. 1: On the Geology of the Environs of Nice (c1829)
- Archives 363: H. T. De la Beche notebook
- Archives 364: Letter from H. T. De la Beche to Buckland, 23 July 1829; Change of DLB's views on diluvium
- Archives 367: Awful Changes
- Archives 368: Watercolor version of *Duria antiquior*
- Archives 371: Map
- Archives 372: Letter from De la Beche, noting advantages of geological maps
- Archives 377: *The Mining Chronicle*, 1837
- Archives 384: State of the Survey of England in January 1838
- Archives 395: Caricature, *The Irregularities of Sol Visited Upon His System*
- Archives 396: Letter from De la Beche, discussed lithographs
- Archives 415: Portrait (engraving) of De la Beche 1848
- Archives 422: photographs of De la Beche & family
- Archives 431: Illustration of trilobite
- Archives 432: caricature, A Coprolitic Vision
- Archives 433: Sketchbook of De la Beche

Archives 434: Sketch for Plate 6 in *Report on the Geology of Cornwall, Devon and West Somerset*, 1839

Archives 435: Map and sections

Archives 436: sketch of Snowdon Peak

Archives 437: Geological Map of Gulf of Spezia.

Archives 438: watercolor sketches

Archives 439: leaf rubbings and sketch

Archives 440: Sketches

Archives 459: Letter from L. W. Dillwyn, 16 Feb 1846; “congregation of rats”

Archives 489: Letter from Elie de Beaumont, discussing *Tabular View*

Archives 495: Letter from Elie de Beaumont, 4 January 1832; sketch

Archives 496: Letter from Elie de Beaumont, 5 February 1832; translation of DLB’s second edition

Archives 497: Letter from Elie de Beaumont, 8 April 1832; mentions 1st vol of Lyell's *Principles*

Archives 500: Letter from Elie de Beaumont, 20 December 1834; mentions *Researches in Theoretical Geology*

Archives 522: Letter from Enys, John, discusses completion of figures.

Archives 524: Letter from Enys

Archives 537: Letter from Wm. H. Fitton, 18 July 1842; discusses Darwin and Buckland

Archives 559: Letter from Edward Forbes, 26 July [1847 FJN]; discusses teaches his wife fossil-ology

Archives 609: Letter from Richard Gibbs, 28 Nov 1849; sketches of trilobites

Archives 836: Letter from Kerr, H.B, 2 August (1835?); discusses *How to Observe*

Archives 929: Letter from Mantell, 1848 (FJN); discusses the jaw of Igaunodon

Archives 1039: Letter from James Nasmyth, 2 July 1842; sketch of rock types

Archives 1153: Letter from Owen, 20 December 1853; thank you for *British Organic Remains*

Archives 1339: Letter from John Phillips, 22 April 1840; Position of Lias sketch

Archives 1453: Letter from John Phillips, 23 Aug 1842; sketch of section

Archives 1470: Letter from John Phillips, 28 Nov 1842; thanking DLB for sketch, also included sketch.

Archives 1484: Letter from John Phillips, 29 December 1842; discussion provisions for illustrations

Archives 1564: Letter from John Phillips. 21 Oct 1844; discusses sketches, wood cuts

Archives 1870: Letter from Sedgwick, 7 March 1830; includes sketch of

Archives 1881: Letter from Sedgwick, (?Nov. 1843); wants Welsh sections

Archives 2004: Letter from S. Stutchbury 19 May 1843; includes sketch

Archives 2230: *Illustrated London News*, 8 April 1848; The Museum of Economic Geology

Archives 2231: *Illustrated London News*, 24 May 1851; Opening of the Museum of Practical Geology

Archives 2232: Map of Bristol, Clifton, and the Hot-Wells

Archives 2246: Passport

Archives 2280: Medals

Archives 2281: Medal

Archives 2283: Small bust of De la Beche



## Archives, British Geological Survey

AM11125 Unarchived map of Devon, owned and annotated by DLB

GSM 1/4 Entry Book of In-And-Out Letters 1845 - 1846, DLB Instructions for the Local Directors of the Geological Surveys of Great Britain & Ireland

GSM 1/5 Entry Book of In-And-Out Letters 1848 – 1852. DLB's letter to prevent explosions in colliers.

GSM 1/123: Notebook By DLB.

GSM 1/123ii: De la Beche's field book

GSM 1/558: Duria Antiquior, and caricatures in Murchison's geological scrapbook

GSM 1/565. Geological Notes, bound with blank pages between for DLB's notes.

GSM 566: Geological Manual, with blank sheets between pages for annotations

GSM 1/830: Diary of De la Beche

GSM 1/831: Early diary of De la Beche

IGS1/815 ichthyosaurus sketches, attributed to De la Beche

## Archives, Geological Society of London

LDGSL 94: Lithograph view of Jamaica, by De la Beche

LDGSL 98: Map and sections of Weymouth by De la Beche

LDGSL 225: Map of Lake Geneva, Switzerland by De la Beche

LDGSL 256: Paintings of belemnites by De la Beche

LDGSL 312: Painting of a Geological Society meeting by De la Beche

LDGSL 400/59: Painting of forest at Stolford, watercolor by De la Beche

LDGSL 400/61: Painting of Zennor Cliff by De la Beche

LDGSL 587: Print of a trilobite by De la Beche

LDGSL 635: Print of a crocodile by De la Beche

LDGSL 640: Print of ichthyosaur skull by De la Beche

LDGSL 641: Print of ichthyosaur by De la Beche

LDGSL 642: Print of an ichthyosaur by De la Beche

LDGSL 646: *Duria Antiquior* by De la Beche

LDGSL 905: Awful Changes caricature by De la Beche

## Appendix F: Interview Guidelines

### Interview Guideline, Dr. Martin Rudwick

1. I focused my pilot study research on early geologic illustrations on the early modern period of geology, beginning with Hutton's 1788 paper, and continuing through "The Golden Age of Geology;" the end of which is defined for my purposes as 1840. If I asked you to name geology texts of this period that you felt were aimed at educating the public, which text authors would you name?
  - a. Are these authors different from the most important geological writers of the time?
  - b. How do you think Mantell fits in with early geology texts, and their illustrations?
2. Will the Transactions of the Geological Society reveal papers similar to the texts of the time; will it give a broad overview of what was being published?
  - a. Did it have any innovations or conventions not found in texts? Was it missing any innovations or conventions found in contemporary texts?
3. In *Scenes from Deep Time*, you discussed the potential of illustrations; In particular, you stated that it was Phillips and Boblaye who "realized the popular potential of illustrations that their publishers, on their own, might never even have known about." How educational do you think their intentions were? How do you feel this compares with DLB's illustrations?
4. You mentioned in an early email to me that you believed DLB's *Sections and Views* was particularly innovative; why do you think this is so?
5. How do you feel De la Beche was treated differently than other geologists of his time, as far as the standard Victorian life & letters? (Why?)
6. The caricatures that DLB drew were a new type of geologic illustration for me. What purpose do you think DLB's caricatures served?
  - a. How were they distributed?
  - b. Were any published in a book/journal format during their time?
7. What do you think were the effects of DLB illustrating his own texts?

8. DLB's geological texts were unusual in that he drew his illustrations himself. However, it was also customary at this time that authors not give credit to their illustrators. Are you aware of a certain time after which DLB did not illustrate his own texts?
  - a. For example in the text, De la Beche, H. T. *Catalogue of Specimens in the Museum of Practical Geology, Illustrative of the Composition and Manufacture of British Pottery and Porcelain, from the occupation of Britain by the Romans to the Present Time* by the late Sir Henry De la Beche, C. B., Director, and Trenham Reeks, Curator. Third Edition by Trenham Reeks (curator) and F. W. Rudler (Assistant Curator) **1876** London: George E. Eyre and William Spottiswoode rebound HOW MUCH IS BY DLB? WRITINGS? FIGURES?
9. How did changes in printing techniques affect illustrations in the period 1788 – 1840?
10. Much of the history of geology is lost in the field of geology. Do you feel students of geology would benefit from the inclusion of the historical struggles? Of the information on DLB?

## Interview Guideline, Mr. Tom Sharpe

1. Which of DLB's publications do you believe was particularly innovative?
2. How do you feel De la Beche was treated differently than other geologists of his time, as far as the standard Victorian life & letters? (Why?)
3. The caricatures that DLB drew were a new type of geologic illustration for me. What purpose do you think DLB's caricatures served?
  - a. How were they distributed?
  - b. Were any published in a book/journal format during their time?
4. What do you think were the effects of DLB illustrating his own texts?
5. DLB's geological texts were unusual in that he drew his illustrations himself. However, it was also customary at this time that authors not give credit to their illustrators. Are you aware of a certain time after which DLB did not illustrate his own texts?
  - a. For example in the text, De la Beche, H. T. *Catalogue of Specimens in the Museum of Practical Geology, Illustrative of the Composition and Manufacture of British Pottery and Porcelain, from the occupation of Britain by the Romans to the Present Time* by the late Sir Henry De la Beche, C. B., Director, and Trenham Reeks, Curator. Third Edition by Trenham Reeks (curator) and F. W. Rudler (Assistant Curator) **1876** London: George E. Eyre and William Spottiswoode rebound HOW MUCH IS BY DLB? WRITINGS? FIGURES?
6. How did changes in printing techniques affect illustrations in the period 1788 – 1840?
7. Much of the history of geology is lost in the field of geology. Do you feel students of geology would benefit from the inclusion of the historical struggles? Of the information on DLB?

## Interview Guideline, Mr. Graham McKenna

1. How is DLB regarded in the British Geological Survey?
2. How do you feel De la Beche was treated differently than other geologists of his time, as far as the standard Victorian life & letters? (Why?)
3. Which of DLB's publications do you believe was particularly innovative?
4. The caricatures that DLB drew were a new type of geologic illustration for me. What purpose do you think DLB's caricatures served?
  - a. How were they distributed?
  - b. Were any published in a book/journal format during their time?
5. What do you think were the effects of DLB illustrating his own texts?
6. DLB's geological texts were unusual in that he drew his illustrations himself. However, it was also customary at this time that authors not give credit to their illustrators. Are you aware of a certain time after which DLB did not illustrate his own texts?
  - a. For example in the text, De la Beche, H. T. *Catalogue of Specimens in the Museum of Practical Geology, Illustrative of the Composition and Manufacture of British Pottery and Porcelain, from the occupation of Britain by the Romans to the Present Time* by the late Sir Henry De la Beche, C. B., Director, and Trenham Reeks, Curator. Third Edition by Trenham Reeks (curator) and F. W. Rudler (Assistant Curator) **1876** London: George E. Eyre and William Spottiswoode rebound HOW MUCH IS BY DLB? WRITINGS? FIGURES?
7. How did changes in printing techniques affect illustrations in the period 1788 – 1840?
8. The period of my focus in early modern geology is that time between 1788 and 1840. Are there any geological texts of which you are aware that were particularly educational?
9. Much of the history of geology is lost in the field of geology. Do you feel students of geology would benefit from the inclusion of the historical struggles? Of the information on DLB?

## Appendix G: Itinerary for the History of Geology Group Field Trip, July 13-14, 2002

### July 13, 2002

**Locality 1:** Batheaston; site of one of the world's scientifically based mineral prospect (coal boring under William Smith, 1804 – 1813).

**Locality 2:** No. 29 Great Pulteney Street, residence of Smith's supporter, Rev. Joseph Townsend; location of Smith's dictation *Natural Order of the Strata*

**Locality 3:** Trim Street, site of Smith's office 1802 – 1805, and where he arranged his fossils in stratigraphical order for public inspection.

**Locality 4:** Bloomfield Crescent, Smith's home 1795 – 1798 from where he supervised contracting work on the Somerset Coal Canal.

### July 14, 2002

**Locality 5:** Sutton Court, ancestral home of John Strachey, from where he described local coal mining practice.

**Locality 6:** Stowey House, residence of Strachey's sister, Elizabeth Stowey.

**Locality 7:** Rugbourn Farm and site of Mearns coal work, High Littleton; Smith resided here 1791 – 1795 while surveying.

**Locality 8:** Dunkerton Wharf, Somersetshire Coal Canal

**Locality 9:** *The Old Swan*, Dunkerton; Smith often used the inn. His most famous of notes expressed his belief of fossils: Nature had "assigned to each Class its peculiar Statum."

**Locality 10:** Farleigh Church and Rectory, Benjamin Richardson's church. Smith discussed the nature of fossils with Richardson circa 1797.

**Locality 11:** Broadfield Farm, near Hinton Charterhouse, where William Smith's brother John lived. John was William's occasional assistant.

**Locality 12:** Hill Farm, near Pipehouse, Midford; site of Cornbrash outlier on Smith's stratigraphical map.

**Locality 13:** Tucking Mill House, Midford; purchased by Smith in 1798, and originally consisting of the western half only.

**Locality 14:** Caisson House, Combe Hay; site of failed experiment to transfer coal boats from upper to lower levels without conventional locks.



## Appendix H: Transcripts of Interview Field Notes

Interview with Dr. Martin Rudwick

July 3, 2002

3 The Blackbirds

Ely, England

Recommended dissertation:

Mark Hinline

University of California, San Diego

Ph.D. dissertation in History of Science

[hinline@helix.ucsd.edu](mailto:hinline@helix.ucsd.edu)

Use of visual illustrations in American geology

Late 19th – early 20th century

Interpret & understand illustrations as a function of illustrations

Proxy: Illustration stands for real thing

Landscape, fossil

Designed to give reader a proxy experience, standing in front of object

Diagrams: Sections, maps, (all others)

Duria Antiquior: pseudo proxy, imaginative reconstruction.

DLB was insistent, drawing should be at natural scale, no vertical exaggeration. With vertical exaggeration, you come to false conclusion.

Natural scale: makes more of a proxy

Artistic: offshore views of coastal cliffs, natural sections/proxies

True section: looks like a natural cliff

“Natural section”: when extrapolated to surface.

BEGIN RECORDING

Pictures of reality.

*Sections and Views*

Conventional in illustration

Must look at purpose of books. . .

For DLB, education, general, & to supplement

*Geological Manual* purpose = instruction

*Sections & Views* purpose = provide series of proxies.

DLB made a point of sitting on the fence. Right theory? Take data into account.

Typical of the period

Lyell was ATYPICAL, free with theory

Hutton = large scale theorizing.



Pyramid- much theorizing  
resting on a small base

observations

Playfair sanitized it, removed metaphysical foundations

Illustrations = explanations

Use of illustrations were as examples, words, & images

Amazing shift occurred from very little inclusion (expensive to print) to routine use of a lot of illustrations

Lyell – When did he become known as a geogod? No one yet investigated this!

Lyell's ideas unpopular at first

Early, not viewed as he is now.

(What history chooses to remember)

Specific to Britain – the social classes of geologists

Not so on Continent, where dozens of “geologists” in place

Terms used: geognosy = stratigraphy

Natural history

Natural Philosophy

Sciences more professionalized outside of Britain

It was practical in Europe to have mining schools, where business aspects & structure of rocks were studied.

DLB: major role in 1850s, School of Mines (Continental schools established 1760 – 1790)

DLB good choice for Geological Survey; noted for good contacts in Europe.

1824 translated *Annales des Mines*

Later *Annales des Mines*, identical in title. Was it a 2nd edition or new changes?

Humboldt? Outstanding scientist!

More known for physical geography.

DLB's *Researches in Theoretical Geology*

Stodgy – very small print

Abandoned illustrations, not many illustrations

Wood Engravings

“Wood-cuts”

Carved end grain of very hard boxwood

Could make many copies, same as lead type

Started out as fine art. . .

Investigate Thomas Bewick (History of Art, early 19th century)

Came into use in 1820s

Note from 1830 to 1833 volume of Lyell, illustrations increased.

DLB's scene from deep time

Rather large, expensive picture

## CHANGE TAPE

Types of texts

Specific texts – model for other people

Innovative ones have implications, suggest how to tackle similar situations, problems

### Textbooks

*Geological Manual*

Conybeare & Phillips . . . a little of both. . . .

Vs.

### Specific Geology

Murchison's *Silurian System*

model of how to make sense of strat. Out of

old rx, Murchison

applied Smith's map

Smith's Map

Cuvier

Lyell: elementary book, with novel perspective

Controversial, provoked thought

Bridged discourses of textbooks & specialized geology

Addressed both, dual audience

Suggestion: Review the secondary literature instead of texts

Anthology of Cuvier by Rudwick, early paleontology

Interpretive essays on Cuvier

Cuvier took first steps toward deep time

Never published reconstructions in life-like position with musculature & skin; not acceptable to science then.

Was DLB unusual for helping Mary Anning?

Not necessarily. However, *Duria Antiquior* was unusual.

Gentlemen of time passed hat around for collectors, not unusual in Anning's case;

They got something out of it to.

Investigate: Simon Knell

*The Culture of English Geology, 1815-1851*

2000

Ashgate, Burlington USA

Collectors saved upper class people time.

Believes Anning was only a collector

Anning not able to interpret, based on letters

However, a large part of historical record is missing

Some women in science

Mary Summerville = most celebrated

Translated mathematics

Astronomy

High social status (advantage)

Anning

Specimens only

Reliable info of location of find

Skilled collector

Was DLB ignored because he had no theoretical ideas?

Might be something in that.

History extracts figures differently than the way they are viewed in their time

Practitioners = effective, reliable, solving routine problems

DLB highly respected for mapping

Geological texts: Was Lyell worried about DLB's books?

Lyell was a different market, but did have \$ considerations. . .

Recast his books

Mantell wrote elementary texts

*Transactions of the Geological Society*: Were the illustrations different from texts?

Probably not, first glance not.

Detailed research not required for this. . .

Types of illustrations:

Copper Engraving

Main medium,

Continued in use until

19th century

Vs.

Lithography

Cheaper medium

Still inserted as plates

Finer detail

CHANGE TAPE

Important to note what illustration did author choose to use as a frontispiece?

Usually this was most expensive, most important

Lyell chose Roman ruins

Historians aren't trained to look at pictures.

Progression from wood cuts, to copper engraving

Sometimes plates were bound as separate volume, bibliographer's nightmare

Easy for viewer to use.

Choice of illustrative technique:

"Swings & roundabouts"

Advantages & disadvantages:

Geologic section? Wood engraving was probably enough detail

Method depended on type of information that was needed to convey.

Ammonite specimen would need sophisticated drawing; lithography more  
Appropriate.

#### Print Shops

Sold images for portfolios, wall art  
Static images kept, as a library.  
People collected these as now they do VCR tapes  
Example: 1831, prints of a one-day wonder, volcano

#### “Awful Changes”

Made before the debate, so he could sway debate in his favor  
Reproduced through 19th century  
Cuvier had a copy, so it reached the continent.  
DLB did his own lithography  
Was “Coprolitic Vision” also reproduced this way??? (Only knows about “Awful  
Changes” & *Duria Antiquior*)  
Field notebooks: All images were in preparation for “Awful Changes;” doesn’t  
Believe anyone else ever saw notebooks.  
Not published in book/journal during their time.

#### Religion & Geology

Anti-Roman Catholic at time, with RC church attacked for superstition.  
Diluvium, Noah’s flood.  
Bible seen as “history”  
Geologists were uncovering a reliable history of earth, & asked, “How do you  
relate human history to earth history?”  
Natural thing to look at geology and find evidence for Noah’s flood. (RG: like  
Schliemann at Troy.)  
Religion sanitized geology texts, used as sort of protection??

#### Phillips, Mantell

Mantell was keen on spreading knowledge  
Appealed to much large public  
*Penny Magazine* (Susan’s article)  
Effective at getting across something that would sell.

DLB also had several markets.

#### CHANGE TAPE

#### Social changes happened during DLB’s career

He was unusual at the beginning of his career  
Britain did catch up with continent.  
DLB was a role model/catalyst  
Greater government involvement  
Played patriotism card  
Surveys

Geological Survey: DLB shamelessly used patriotism argument (France had sent over people earlier to try to catch up with Great Britain!)

Self-serving? All of us are to a certain extent.

He was interested in a career, but believed there ought to be other people like me!

DLB: Unusual as an artist?

He was a good artist

Very widespread artistic skills.

Significant that most geologists were reasonably good artists.

DLB was better.

Advantage to cut out an intermediate step in publication process.

More control

Did DLB stop drawing his illustrations?

SOMETHING TO INVESTIGATE!

Catalog might be exception, although probably maps (There were better map makers)

Obviously cared about his pictures.

Frontispiece, 1834 *Researches in Theoretical Geology* (Charles Knight)

View of world from outer space, drawn by DLB himself!

Agrees that much of history of geology is today lost in field of geology.

Interview with Mr. Tom Sharpe  
 July 11, 2002  
 National Museum of Wales  
 Cardiff, Wales

DLB publication that is innovative?

*Sections & Views*

Unusual, no one else was doing this, and his reasons: wanting to make known to people (scientific community)

1830 (early)

DLB influenced by his early tours.

No correspondence to indicate people of his time thought the book was great,

Scathing to geologists who proposed theories

He knew they were dealing with a young science, & there was no evidence

Tried to bring elements back, NOT theories

Jamaica:

Theory of British geology transplanted to Jamaica by DLB

Encountered problems

In 1823 (only 27 years old)

1816: Tour of Scotland

Notebook at BGS

Main introduction to geology??

Probably 1811, Lyme Regis

Contacts with Mary Anning

Many different schools after his father died in 1801.

Shipwrecked when he was 5 years old, Great Inagara

Notice in BGS of shipwreck in 1801 (with mom?)

How was DLB treated differently?

Buckland & Sedgwick were recognized, but had chairs at Oxford, Cambridge

DLB had the Survey, Mining Record Office, Geological Museum (part of the

British Museum), plus original research

Ichthyosaurs – he named 3 species

1817-1819?

Published in 1821

Plesiosaurs

Jamaican geology

Difference?

DLB was mapper, he produced things of utility for other geologists.

Less work on scientific pursuits

More on Utility of Science!

Connection with Prince Albert, who was a scientific supporter/technology supporter

Coal Survey: Welsh coal has different coal ranks (from bituminous to anthracite), steam coal in between

1840s-1850s

idea to produce steam, not lots of smoke.

#### Other Caricatures?

Conybeare (of Buckland), & only other caricatures are by DLB

Why?

DLB had a wicked sense of humor

Was expressing humor, feelings; a sort of release

Especially in Devon controversy, against Murchison & Sedgwick

Controversy erupted Bristol, 1836

Felt threatened, depressed

Challenged over the way he made a living

Awful Changes

Against Lyell

Duria Antiquior

For Anning

Irregularities of Sol

1840 glacial theory of Agassiz, in Glasgow

Drawn in Cardiff, 1841, at home of Wm. Henry Smyth, who was working on Cardiff Bay

DLB was in South Wales. Place was a farm, estate. Still exists, Colleena Newbridge between Cardiff & Bridgend

Diluvium went out the window, & Buckland changed his mind.

Personal amusement

Awful Changes: 25 copies in Museum, so probably 30 originally?

DLB's supply was in Cardiff.

Probably 50 – 100 originally printed.

DLB was giving them away????

Duria Antiquior

Buckland asked him perhaps to do this?

Pencil sketches on the back of the watercolor.

Giving new directions, changes to lithographer

Several versions

Proceeds going to Mary Anning.

Not cheap.

Geology customers could buy it, but not something Wm. Smith could afford

Clergy, professional

Leisure class

Murchison

Hints of bits of caricatures in publications

2nd version, *Geological Manual*

Innovative

1st to show deep time

Aquarium view

No real caricatures in publication

Closest publication 1860s, Figuier, *World Before the Deluge*.

Hawkins, a “maniac”



1834, 1840?

*Memoirs of Ichthyosauri, Plesiosauri*

Frontispiece deep time

He was a collector, eccentric

Not taken seriously

Collector in Lyme Regis & Street

Used flowery language

Included local dialogue

Popular, though (NOT scientific)

Mentioned in *Dinosaur Hunters* by Deborah Cadbury

Similar genre to *The Map That Changed the World*

Conybeare noted in a letter, What capital fun Hawkins book, geological bore, etc.

Effect of DLB's illustrations?

Good illustrator

Cut out middle man

Others had to use geological artists

Thomas Webster

Not greater authenticity, though

Not acclaimed for his own sketches

There were many illustrators.

DLB was better than many.

Did he stop drawing?

As Director of Survey, he had staff, no time

Probably did not draw for *Catalog of Specimens*

For *Geological Observer*, he probably provided sketches, made notes to artist for changes

CHANGE TAPE

In the 1830s, it was easier to draw than to instruct.

Noticed some differences in illustrations in *Sections & Views*

Quality difference between some illustrations

Jamaican stuff is rougher

Some illustrations did not give an accurate depiction

Glen Tilt, the granite/schist of Hutton

Scale is off from illustration.

In illustration, man against the rock, but it is only 2 feet in real life.

Should we bring DLB into the classroom?

Yes!

History gives us a context

Provides an historical perspective

Most students don't know about the struggles with the geological time scales.

It is an artificial construct  
Involved personalities  
    Cartoons show humor  
    Geologists were human!

Interview with Mr. Graham McKenna  
 July 16, 2002  
 British Geological Survey  
 Keyworth, England

How is DLB regarded by the Survey?

As the founder, very well  
     1st geological survey in Britain  
 Not same status as Hutton, Lyell, even Wm. Smith  
 Why? Was he a reticent person?  
 Definitely had a certain amount of influence,  
     Persuaded Ordnance Survey to give him \$

Why is he remembered differently?

“Ideas” versus procedures, mapping  
 More practical applications  
 In the Geological Survey, practical applications, leg work  
 DLB actually did the mapping.  
     Not the same clout as those that theorized about it.  
 Not seen as an “in” person, but he undoubtedly was.  
     Opening of the Museum of Practical Geology  
     Prince Albert was there  
     Actually got the museum built from ground up  
     Very fashionable area, Jermyn Street  
     Backed into Piccadilly  
     Prime site

Which of DLB’s books is innovative?

*How to Observe*  
     Has elements of education, teaching  
 DLB also encouraged working man’s lectures  
 No major opus like Lyell, though

Caricatures

Sort of illustrations, like cartoons, in the newsy journals (such as “Punch”)  
 He saw an issue, put it in visual context  
     Saw controversy there, then drew it.  
     DLB more comfortable in drawing  
 Doesn’t believe they were published at this time  
     McCartney’s 1977 book published several of DLB’s

Effect of DLB illustrating his own texts?

Drawing skills were relatively common  
     Murchison did sketches  
     Field geologists were observing & making notes  
     They were used to it, no photography.  
 However, unusual for topography shown in Devon map

Almost equate it with someone currently in Survey, preparing for publication, & wanting to take an outstanding feature of an area he/she had seen & making a pictorial reminder.

Did he continue to draw his own illustrations?

Most evidence points that before 1855, he was drawing his own at least.

Catalog of specimens: some sort of professional, probably

Records in letterbooks?

People were taught how to draw accurately

Such things (art, sketching) included in curriculum.

Any other geological texts that are educational?

No.

Nothing to the same extent as DLB.

He was going out of his way to set up the museum, set up lectures

Geology was different

In physics, Faraday

The only other demonstration, learning situation was medicine

Most physicians held this knowledge close to themselves

Not sure what mixture of geology & DLB was responsible

How much was nature of geology, pushing for geological education, or

Was DLB a spark?

Should history of geology be included in the classroom?

It has potential

Students can see how much the geologists achieved in the early 1800s, without modern tools.

Also, shows students within an individual science, there was an interchange of ideas between disciplines; this is not so visible today.

Geology was done in different ways.

The physics side of it:

Concept of how that fits in, links to other areas of science

Too much specialism today

Survey today tries to break away from this

Staff development program

Overt attempt to get breadth of experience and don't become too narrow.

Experience elsewhere, overseas.

Costs \$\$\$

Limiting factor today

20-30 years ago, the overseas program *developed* geologists.

Murchison traveled, DLB traveled

DLB went to Switzerland

Australia

Influence by DLB

Survey people moved on

Look at Logan, Olden who went to parts of empire to found  
surveys.  
Many Survey people stayed at home  
Hunt – mining records  
Also involved in early development of photography  
Also glass for the Crystal Palace  
DLB influenced a lot of people in a lot of ways  
Through education  
Brought in people like Huxley, Playfair for lectures  
Perhaps his main talent was getting things organized, & educating other  
people!

## Appendix I: Verbal Data Coding Scheme

### **HB** Historical Background Information

**HB – S** Social

**HB – R** Religious

**HB – T** Technological

**HB – T – R** Industrial Revolution

**HB – T – P** Printing Innovations

### **MG** Early Modern Geology

**MG – C** Contributors

**MG – C – T** Theorizers

**MG – C – P** Practitioners

**MG – N** Nature of the Science

**MG – T** Texts

**MG – T – G** General

**MG – T – S** Specialty

### **DC** De la Beche Contributions

**DC – A** Accomplishments

**DC – P** Publications

**DC – I** Illustrations

**DC – I – T** Texts

**DC – I – M** Maps

**DC – I – C** Caricatures

**DC – I – D** “Scenes from Deep Time”

**DC – I – U** Unpublished

### **DE** De la Beche as Educator

**DE – T** Texts

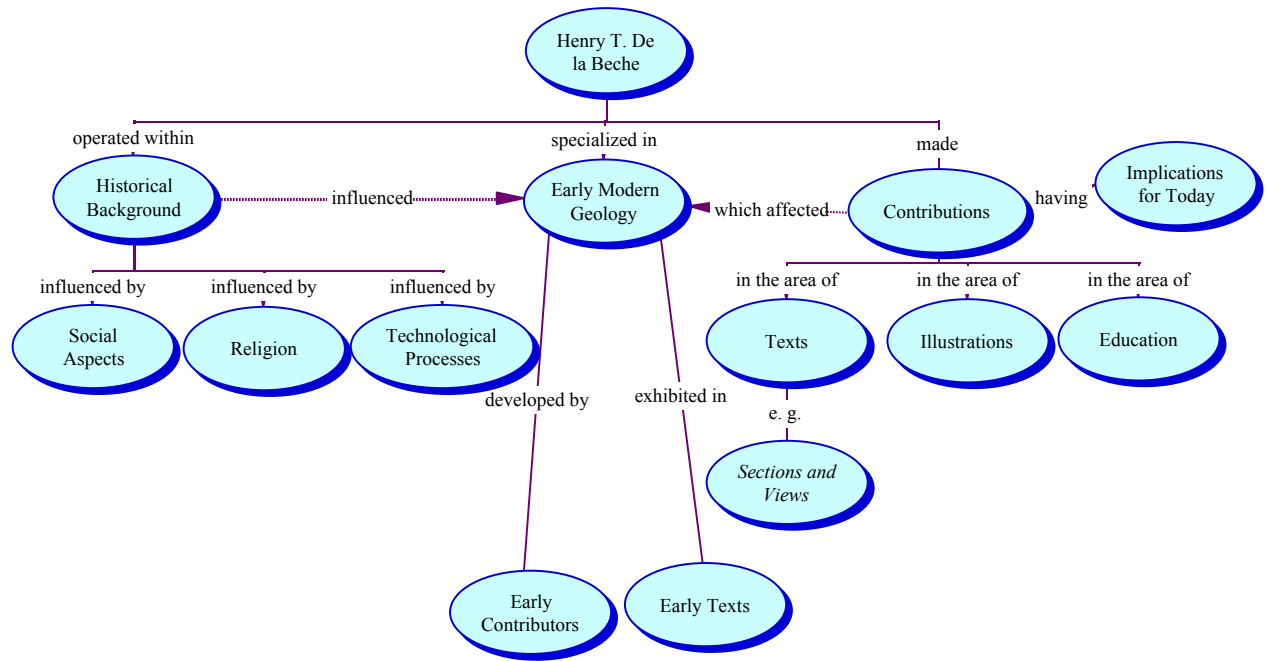
**DE – T – I** Illustrations

**DE – S** British Geological Survey

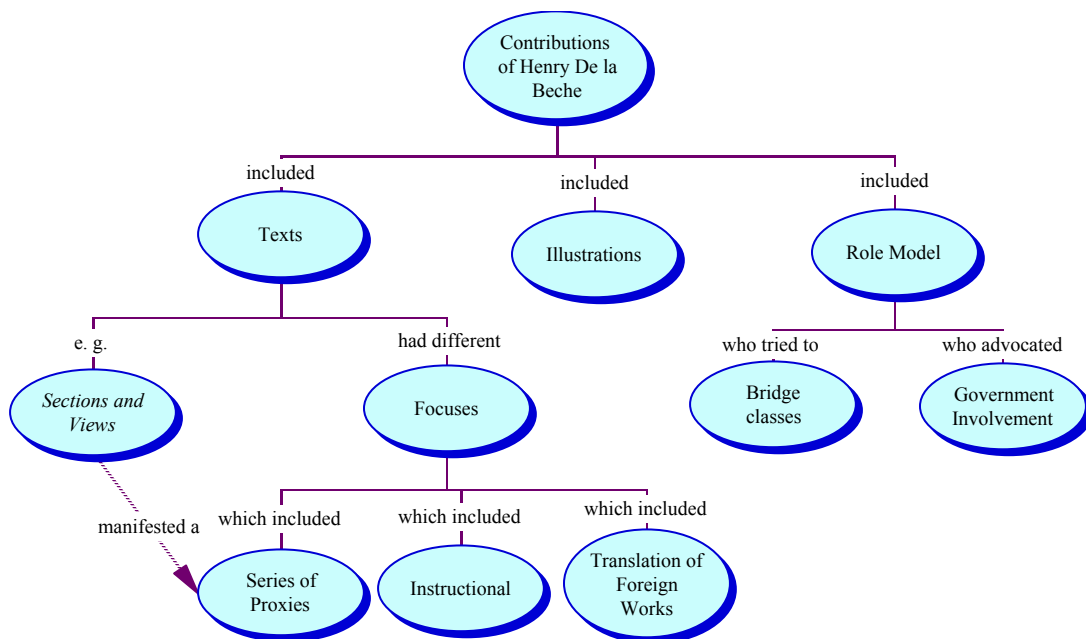
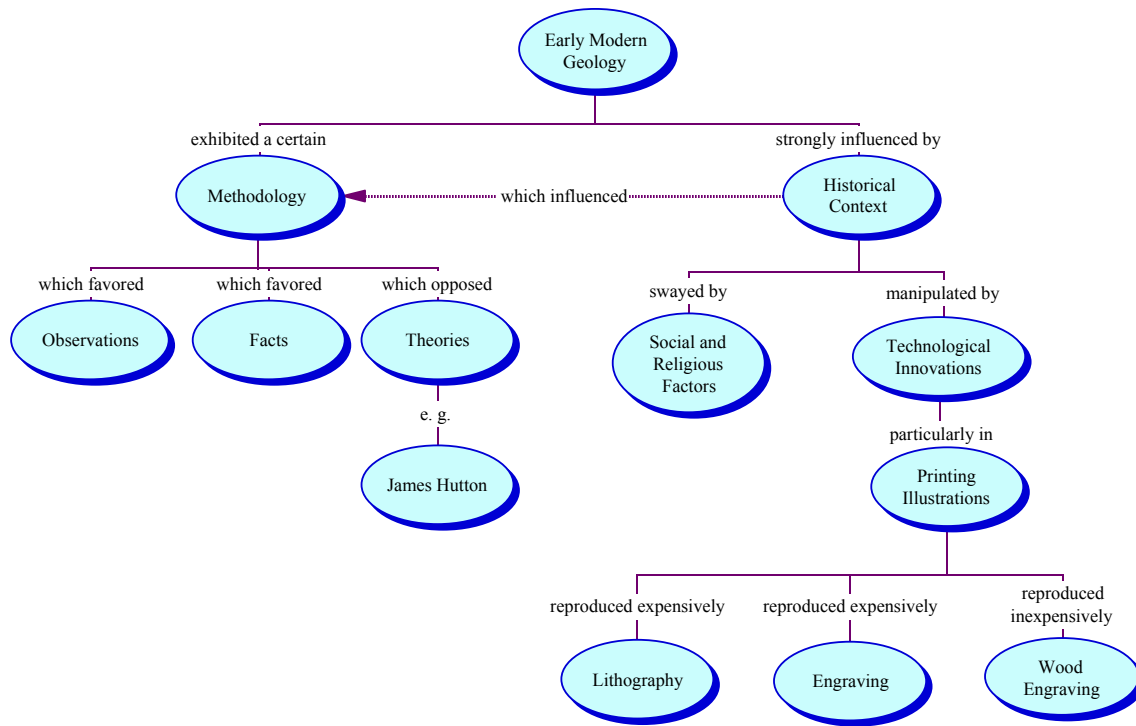
**DE – O** Other Endeavors

## Appendix J: Interview Analysis Concept Maps

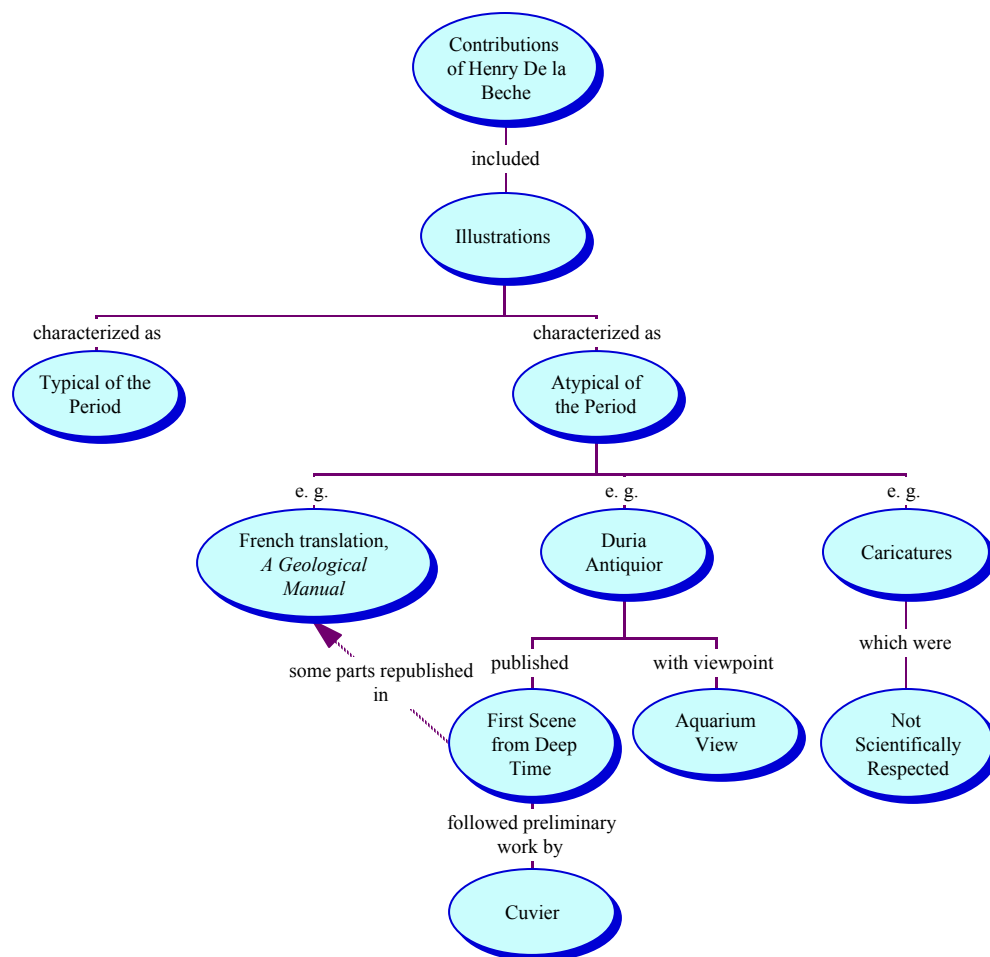
### General Concept Map

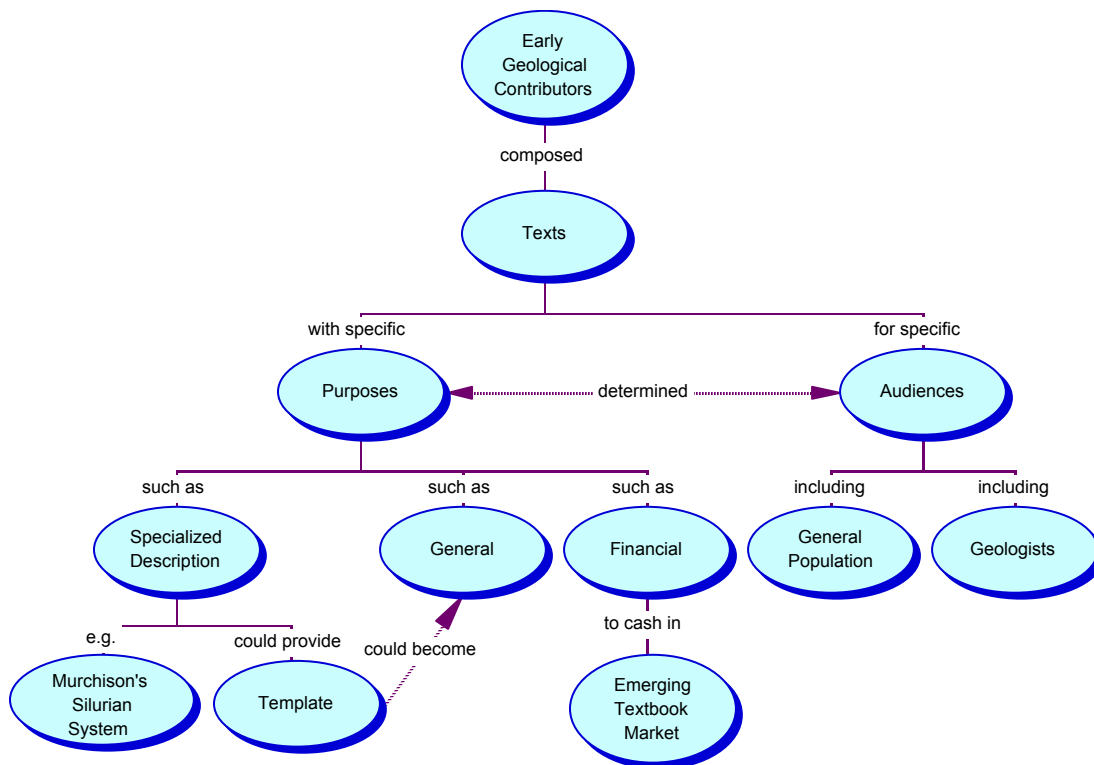
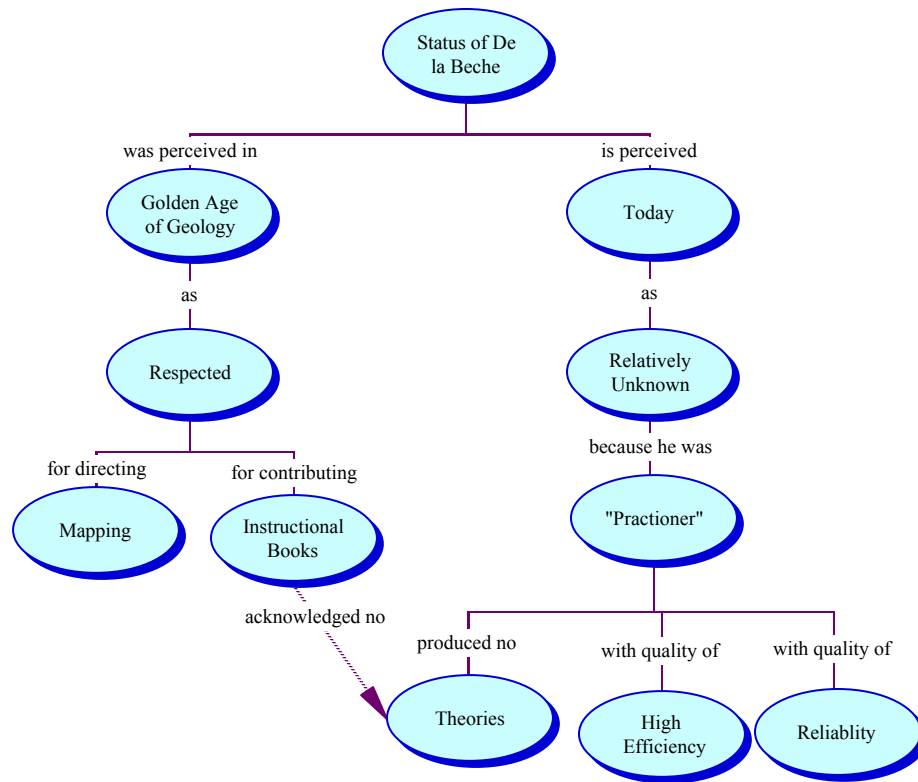


Interview, Martin Rudwick (July 3, 2002)

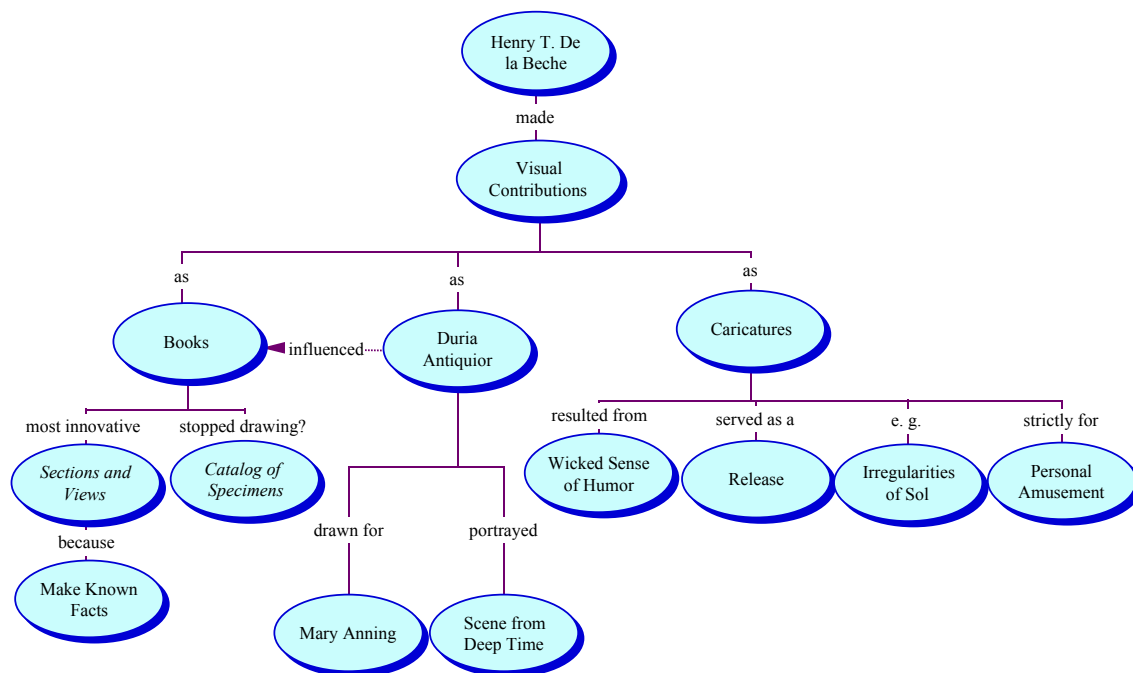
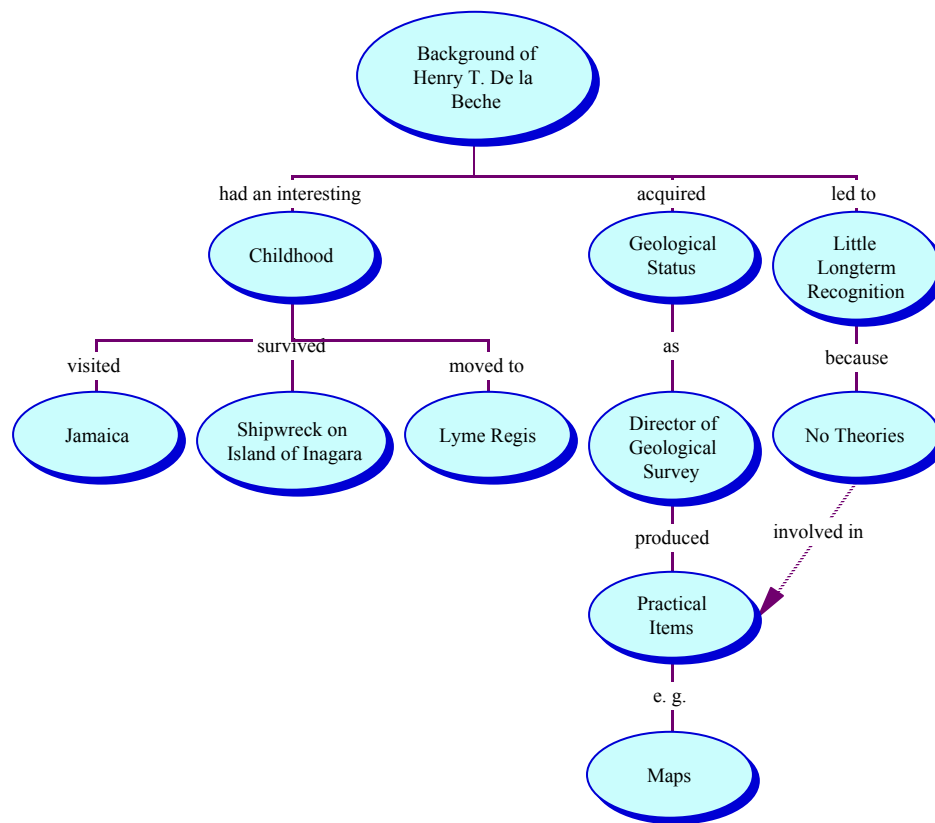


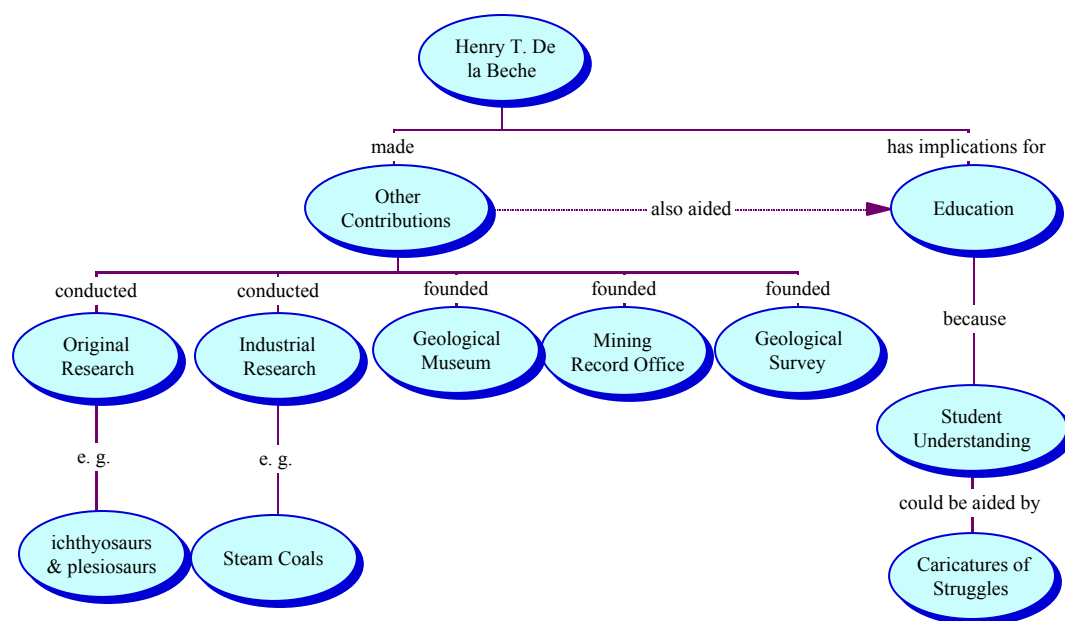




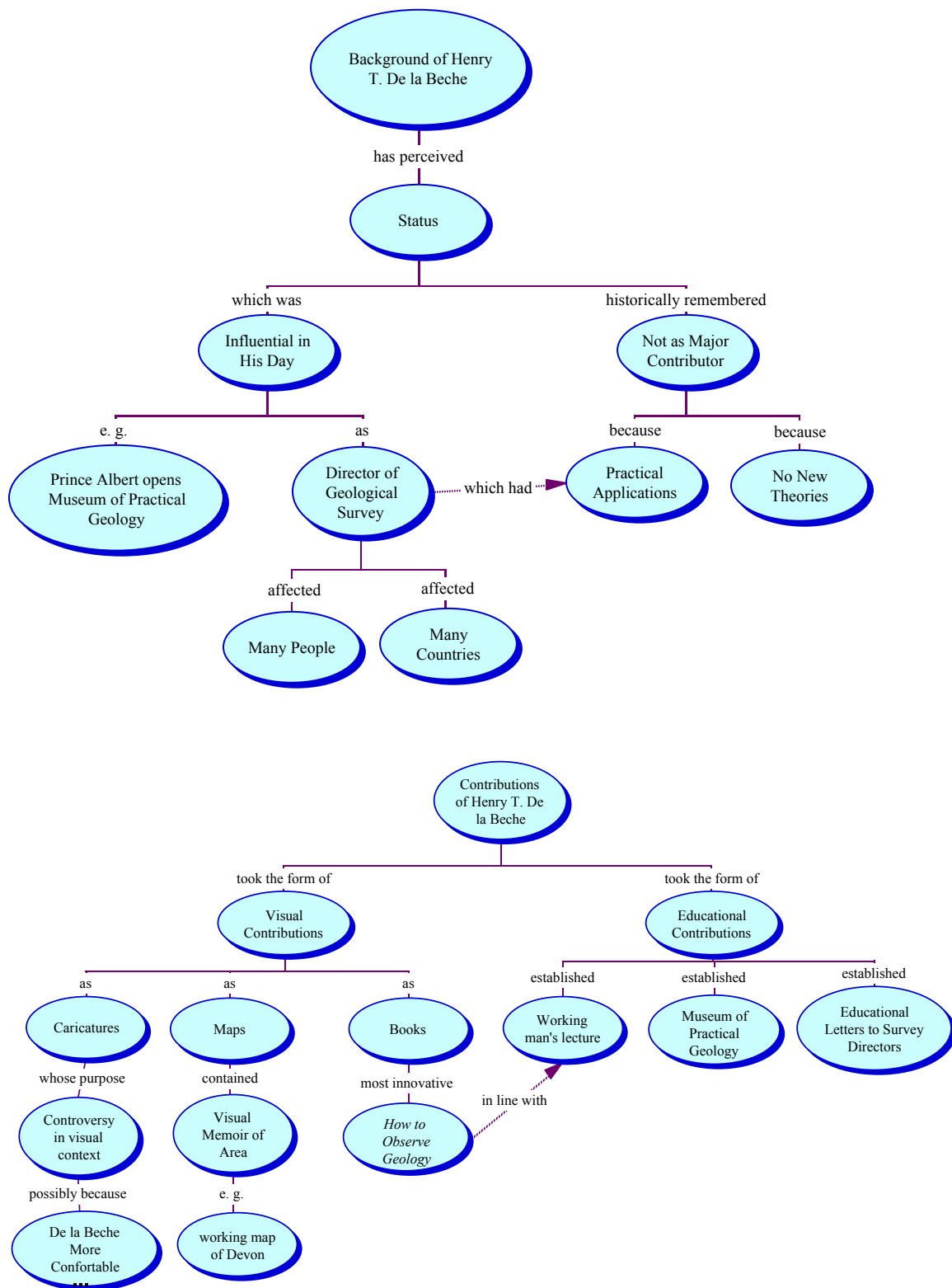


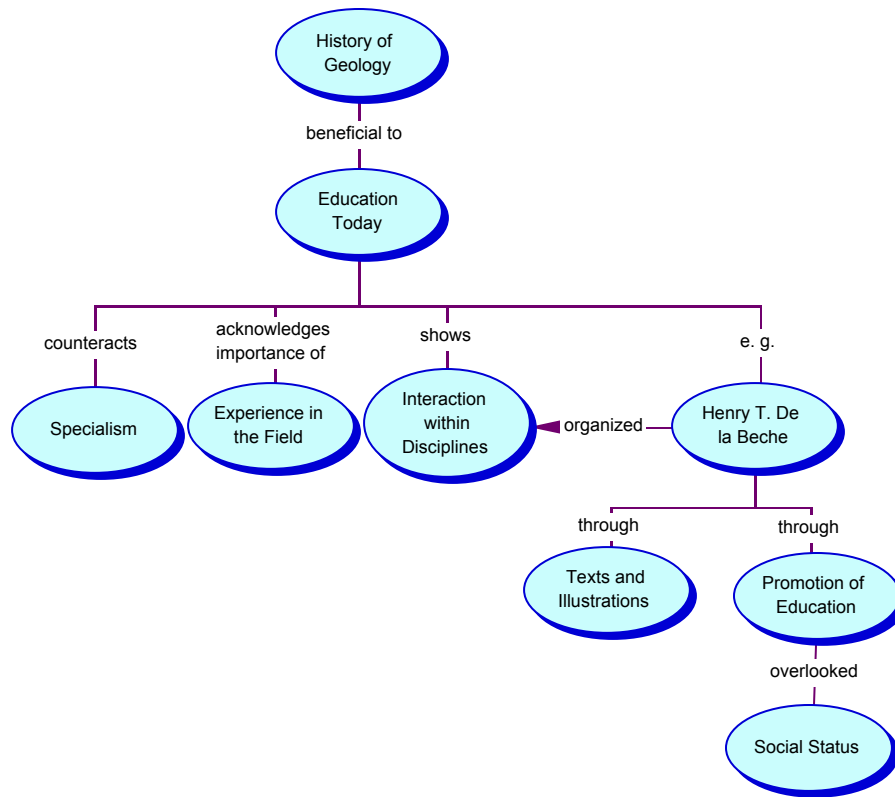
## Interview, Tom Sharpe (July 11, 2002)





Interview, Graham McKenna (July 16, 2002)





## Appendix K: Publications of Henry T. De la Beche

### Periodical Publications:

A=alphabet labels	K=key
C=compass	S=scale
DL =direct labels	WE=wood
HC=hand colored	engravings

On the depth and temperature,	<i>Bibliothèque Universelle</i>	1819	no graphics			
On the depth and temperature of the Lake of Geneva	<i>Edinburgh Philosophical Journal</i>	1820	1 plate	map		DL, S
Sur la température des lacs de Thun at de Zug, en Suisse	<i>Bibliothèque Universelle</i>	1821	no graphics			
Notice of the discovery of a new fossil animal, forming a link between the Ichthyosaurus and crocodile (with Conybeare)	<i>Transactions of the Geological Society of London</i>	1821	3 plates	36 figures	fossils	DL, I, A
Remarks on the geology of the south coast of England, from Bridport Harbour, Dorset, to Babbacombe Bay, Devon	<i>Transactions of the Geological Society of London</i>	1822	8 plates	30 figures	fossils sections	HC, DL, I
Notice respecting fossil plants found at Col de Balme, near Chamouny in Savoy	<i>Transactions of the Geological Society of London</i>	1822	no graphics			
On the geology of the coast of France, and of the inland country adjoining;	<i>Transactions of the Geological Society of London</i>	1822	3 plates		sections fossils	HC, K, DL S
Versuche über das Frieren mit Oel bedeckten Wassers	<i>Annalen der Physik</i>	1822	no graphics			
Notice of a discovery of a large fossil elephant's tusk, near Charmouth, Dorset	<i>Transactions of the Geological Society of London</i>	1824	no graphics			
Catalogue of the birds, and of terrestrial and fluviatile mollusceae, found in the vicinity of Geneva.	<i>Zoological Journal</i>	1825	no graphics			
Notice on the temperature of the surface water of the Atlantic, observed during a voyage to and from Jamaica	<i>Annals of Philosophy</i>	1825	no graphics			
Notice on the Diluvium of Jamaica	<i>Annals of Philosophy</i>	1825	2 WE.	2, in text	section	DL, A
On the Lias of the coast in the vicinity of Lyme Regis, Dorset	<i>Transactions of the Geological Society of London</i>	1826	2 plates	9 figures	section fossils	DL, (K), HC
On the geology of southern Pembrokeshire	<i>Transactions of the Geological Society of London</i>	1826	2 plates, WE		sections map	HC, K, DL
On the Chalk and sands beneath it (usually termed Green-sand) in the vicinity of Lyme Regis, Dorset and Beer, Devon	<i>Transactions of the Geological Society of London</i>	1826	1 plate	4 figures	sections	DL, HC

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HC=hand colored	engravings

Notice of traces of a submarine forest at Charmouth, Dorset	<i>Annals of Philosophy, New Series</i>	1826	no graphics			
Remarks on the geology of Jamaica	<i>Transactions of the Geological Society of London</i>	1827	5 plates	8 figures	map sections	DL, HC, S, K
Nummulites in the Greensand Formation	<i>Philosophical Magazine</i>	1827	no graphics			
On the geology of Tor and Babbacombe Bays, Devon	<i>Proceedings of the Geological Society of London</i>	1828	no graphics			
Notes on the habits of a Caryophyllia from Tor Bay, Devon	<i>Zoological Journal</i>	1828	no graphics			
On the geology of Nice	<i>Proceedings of the Geological Society of London</i>	1829	no graphics			
On the geology of Tor and Babbacombe Bays, Devon	<i>Transactions of the Geological Society of London</i>	1829	2 plates	7 figures	map section fossil	DL, HC, K
On the geology of the environs of Nice and the coast thence to Vintimiglia	<i>Transactions of the Geological Society of London</i>	1829	4 plates	8 figures	map section	HC, DL, K, A
On the geology of the shores of the Gulf of La Spezia	<i>Proceedings of the Geological Society of London</i>	1829	no graphics			
Notes on the differences, either original or consequent on disturbance, which are observable in the Secondary Statified rocks.	<i>Philosophical Magazine</i>	1829	no graphics			
Notice on the excavation of valleys	<i>Philosophical Magazine and Annals of Philosophy</i>	1829	2 plates	6 figures	sections	DL, A
Sketch of a classification of the European rocks	<i>Philosophical Magazine, New Series</i>	1829	no graphics			
On the geographical distribution of organic remains contained in the Oolitic series of the great London and Paris Basins, and in the same series of the south of France	<i>Philosophical Magazine, New Series</i>	1830	no graphics			
On the formation of extensive conglomerate and gravel deposits	<i>Philosophical Magazine, New Series</i>	1830	1 plate	4 figures	maps	DL, C
On the geology of Weymouth and the adjacent parts of the coast of Dorsetshire	<i>Proceedings of the Geological Society of London</i>	1830	no graphics			
Sur les environs de La Spezia	<i>Mémoires de la Société géologique de Paris</i>	1833	2 plates	10 figures	map sections	DL, HC, K, C
On the anthracite found near Bidford in north Devon	<i>Proceedings of the Geological Society of London</i>	1834	no graphics			
Lettre sur la découverte d'empreintes de plantes dans les Schists Subordonnés à la formation de la Grauwacke.	<i>Bulletin de la Société géologique de France</i>	1834	no graphics			



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Note on the Trappean rocks associated with the (New) Red Sandstone of Devonshire	<i>Proceedings of the Geological Society of London</i>	1835	no graphics			
On the geology of the neighbourhood of Weymouth and the adjacent parts of the coast of Dorset.	<i>Transactions of the Geological Society of London</i>	1835	4 WE 3 plates	20 figures	map sections	DL, K, HC, S
Notice of fossils from the schistose rocks of North Cornwall	<i>Proceedings of the Geological Society of London</i>	1836	no graphics			
On the influence of atmospheric pressure on the tidal waters of Cornwall and Devon	<i>Edinburgh New Philosophical Journal</i>	1839	no graphics			
On the connection between geology and agriculture in Cornwall, Devon and West Somerset	<i>Journal of the Agricultural Society of England</i>	1842	no graphics			
On estuaries and their tides	<i>Philosophical Magazine</i>	1844	2 WE	2 figures	map profile	A, DL
Anniversary address of the president	<i>Proceedings of the Geological Society of London</i>	1848	no graphics			
Anniversary address of the president	<i>Proceedings of the Geological Society of London</i>	1849	no graphics			
Geological changes from the Earth's axis of rotation	<i>Edinburgh New Philosophical Journal</i>	1849	no graphics			
Flora of the Silurian System. Plant of the anthracite formation. Geological Climate. Co-existence of Saurian and Molluscous forms. Phosphate of lime in the mineral kingdom	<i>Edinburgh New Philosophical Journal</i>	1849	no graphics			
Analysis of coal from Van Diemen's Land	<i>Papers and Proceedings of Royal Society of Van Diemen's Land</i>	1851	no graphics			

*Note: Some papers were republished in different venues; however, only the original article was considered for this investigation.*

## Book Publications:

A=alphabet labels	K=key
C=compass	S=scale
DL =direct labels	WE=wood
HC=hand colored	engravings

<i>A Selection of Geological Memoirs Contained in the Annales des Mines</i>	1824	335 pages	11 plates	22 figures	map,fossils sections	DL, HC, K A
<i>Reprinting</i>	1836	335 pages	11 plates			
<i>Notes on the Present Conditions of the Negroes in Jamaica</i>	1825	63 pages	1 plate	1 figure	pictorial	
<i>Sections and Views Illustrative of Geological Phaenomena</i>	1830	71 pages	40 plates	137 figures	map, sections	DL, HC, K A
<i>Translation - French</i>	1839				pictorial	
<i>Geological Notes</i>	1830	69 pages	2 plates	9 figures	maps,diag.	DL
<i>A Geological Manual</i>	1831	535 pages	104 WE		sections	A
<i>Reprinting - 2nd edition</i>	1832	535 pages	104 WE		pictorial	
<i>Translation - German</i>	1832	612 pages	24 WE		fossils	
<i>Reprinting - 3rd edition</i>	1833	629 pages	122 WE		diag.	
<i>Translation - French</i>	1833	721 pages	107 WE			
<i>Translation - French - 2nd edition</i>	1837	506 pages	105 WE			
<i>Researches in Theoretical Geology</i>	1834	408 pages	46 WE, 1PL	47 figures	map	
<i>Reprinting</i>	1837	342 pages	46 WE		sections	A, DL
<i>Translation - German</i>	1836				pictorial	
<i>Translation - French</i>	1838	290 pages	46 WE			
<i>How to Observe. Geology.</i>	1835	312 pages	138 WE		sections	A, DL
<i>Reprinting - 2nd edition</i>	1836				pictorial	directional
<i>Translation - German</i>	1836	244 pages	138 WE		fossils	
<i>Translation - French</i>	1838	237 pages	138 WE		metaphors	
<i>Report on the Geology of Cornwall, Devon and West Somerset</i>	1839	648 pages	84 WE	102 figures	map,sections	HC, K, A
			12 plates		pictorial	DL, S
<i>The Geological Observer</i>	1851	740 pages	308 WE		maps,	A, DL, N,K
<i>Reprinting - 2nd edition</i>	1853				sections,	Directional,
<i>Translation - German</i>	1853	624 pages	312 WE		pictorial	C

Note: Gray color means that this version of the text was not examined.

## Official Government Publications:

A=alphabet labels	K=key
C=compass	S=scale
DL =direct labels	WE=wood
HC=hand colored	engravings

On certain phenomena connected with the metalliferous veins of Cornwall: Report of the British Association of the Advancement of Science, Transactions of the sections	London: John Murray	1837	no graphics		
Report with reference to the selection of stone for building the new Houses of Parliament (with C. Barry, W. Smith, & C. H. Smith)	<i>Parliamentary Papers for 1839</i>	1839	no graphics		
Report of the Commissioners appointed to inquire about the facts relating to the ordnance memoir of Ireland	London: W. Clowes & Sons	1844	no graphics		
<i>Report on the state of Bristol and other large towns</i>	London: W. Clowes & Sons	1845	3 plates	maps sections	DL, HC, K S
On the formation of the rocks of South Western England	<i>Memoirs of the Geological Survey</i>	1846	45 WE	sections fossils	A
Gases and explosions in collieries (with L. Playfair)	<i>Journal of the Franklin Institute of the State of Pennsylvania</i>	1847	5 plates 4 WE	maps sections	A,DL, S, HC
<i>First report on the coals suited to the steam navy</i> (with L. Playfair)	London: W. Clowes & Sons	1848	5 plates 2 WE	pictorial	A, S
Mineralogy (chapter in J. F. W. Herschel, ed.)	<i>A manual of scientific enquiry, prepared for the use of Her Majesty's Navy</i> London: John Murray	1849	7 WE	pictorial sections	A
<i>Second report on the coals suited to the steam navy</i> (with L. Playfair)	London: W. Clowes & Sons	1849	no graphics		
<i>Third report on the coals suited to the steam navy</i> (with L. Playfair)	London: W. Clowes & Sons	1851	no graphics		
Inaugural discourse, delivered at the opening of the School of Mines and of Science Applied to the Arts	<i>Records of the School of Mines and of Science Applied to the Arts</i>	1851	no graphics		
Mining, quarrying and metallurgical processes	<i>Lecture to Society of Arts, Manufactures</i>	1851	no graphics		
Note on the Stigmara beds of the South Staffordshire coal field	<i>Records of the School of Mines</i>	1853	no graphics		
<i>Catalogue of specimens illustrative of the composition and manufacture of British pottery and porcelain from the occupation of Britain by the Romans to the present time</i> (with T. Reeks)	London: Museum of Practical Geology	1855	157 WE	pictorial	A

## Appendix L: Quantitative Analysis of De la Beche Graphics

### Graphic Density in Texts:

Book Title	Year	no. of pages	no of plates	total figures	Density*
<i>A Selection of Geological Memoirs Contained in the Annales des Mines</i>	1824	335 pages	11 plates	22 figures	0.066
<i>Reprinting</i>	1836	335 pages	11 plates	22 figures	0.066
<i>Notes on the Present Conditions of the Negroes in Jamaica</i>	1825	63 pages	1 plate	1 figure	0.016
<i>Sections and Views Illustrative of Geological Phaenomena</i>	1830	71 pages	40 plates	137 figures	3.4
<i>Geological Notes</i>	1830	69 pages	2 plates	9 figures	0.13
<i>A Geological Manual</i>	1831	535 pages	104 WE		0.19
<i>Reprinting - 2nd edition</i>	1832	535 pages	104 WE		0.19
<i>Translation - German</i>	1832	612 pages	24 WE		0.039
<i>Reprinting - 3rd edition</i>	1833	629 pages	122 WE		0.19
<i>Translation - French</i>	1833	721 pages	107 WE		0.15
<i>Translation - French - 2nd edition</i>	1837	506 pages	105 WE		0.21
<i>Researches in Theoretical Geology</i>	1834	342 pages	46 WE, 1PL	47 figures	0.14
<i>Reprinting</i>	1837	342 pages	46 WE		0.13
<i>Translation - French</i>	1838	290 pages	46 WE		0.16
<i>How to Observe. Geology.</i>	1835	312 pages	138 WE		0.44
<i>Translation - German</i>	1836	244 pages	138 WE		0.57
<i>Translation - French</i>	1838	237 pages	138 WE		0.58
<i>Report on the Geology of Cornwall, Devon and West Somerset</i>	1839	648 pages	84 WE 12 plates	102 figures	0.16
<i>The Geological Observer</i>	1851	740 pages	308 WE		0.42
<i>Translation - German</i>	1853	624 pages	312 WE		0.50

\*Graphic Density is calculated from total figures / total pages.

## Graphic Analysis of Texts:

Book	Type of Illustration					Nature of Illustration				
	Proxy	Labeled Proxy	Inferred	Mathematical	Small Multiple	Landscape	Map	Section	Fossil	Diagram
<i>Annales</i>	2	13	7	0	0	2	4	13	2	2
<i>Geo. Notes</i>	0	6	3	0	0	2	4	3	0	0
<i>S &amp; V</i>	18	23	88	8	4	24	2	101	0	10
<i>Manual</i>	55	12	35	2	0	6	0	32	55	11
<i>Manual - F</i>	55	12	38	2	0	9	0	32	55	11
<i>Researches</i>	3	25	13	6	1	3	1	10	0	33
<i>Observe</i>	16	110	0	12	0	24	3	1	1	109
<i>Report</i>	19	54	29	0	3	27	6	29	0	40

Book	Quality of Graphic												
	Density			Chartjunk			Multivariate						
	Low	Medium	High	Low	Medium	High	1	2	3	4+	Color	Labels/Key	Annotated
<i>Annales</i>	0	13	9	10	11	1	2	8	8	4	3	19	4
<i>Geo. Notes</i>	3	6	0	7	2	0	3	4	2	0	0	8	4
<i>S &amp; V</i>	18	41	78	106	31	0	15	46	64	12	80	99	36
<i>Manual</i>	49	55	0	84	20	0	68	35	1	0	0	47	0
<i>Manual-F</i>	49	56	0	87	20	0	68	38	1	0	0	47	0
<i>Researches</i>	22	24	0	40	7	0	15	26	6	0	0	39	2
<i>Observe</i>	27	111	0	103	31	4	18	88	31	1	0	119	1
<i>Report</i>	24	67	11	94	8	0	25	59	17	1	2	77	8

## Appendix M: Geological Textbooks Investigated

Author	Text	Year	# Pages	Plates/WE	Additions	Notes
Aubuisson de Voisins	<i>Traité de géognosie</i>	1819	496, 665	1P/0WE, 1P/0 WE	DL=3, Key13	Colors dark, hard to distinguish, figure #s within section
Aubuisson de Voisins	<i>Traité de géognosie, Nouvelle édition</i>	1828 - 1835	524, 629 671	1P/0WE, 8P/0 WE 9P/0WE	DL=8 AL	Colors brighter, but almost garishly loud direct labels on x-sections; chartjunk on plate 3
Bakewell, R.	<i>An Introduction to Geology</i>	1813	362	5 P, 0 WE	DL	4 color, 2 folding
Bakewell, R.	<i>An Introduction to Geology 3rd edition</i>	1829	400	6 P, 2 WE	AL = 21 DL = 6	wood engravings heavily shaded; chartjunk colored plates, reproduces 1813
Bakewell, R.	<i>An Introduction to Geology 3rd ed. From 5th London ed.</i>	1839	596	8 P, 32 WE	AL = 36 DL = 7	added wood engravings; added plates are fossil proxies
Boase, H.	<i>A Treatise on Primary Geology</i>	1834	399	0 P, 24 WE		Primitive wood engravings. Hatchures & speckles have the same line width as lines separating the formations.
Boubée, N.	<i>Géologie Élémentaire</i>	1833	236	1 P, 0 WE	DL = 1	more information than most; infilling of basins
Breislak, S.	<i>Introduzione alla geologia</i>	1811	367, 490	0 P, 0 WE		Photographic views, meant as pictorial representations
Breislak, S.	<i>Institutions géologiques. Traité sur la structure extérieure du globe</i>	1818 - 1822		56 P in atlas		pictorial images
Buckland, W.	<i>Reliquiae Diluvianae</i>	1824	303	27 P, 0 WE	DL,	proxy images, heavy shading
Chenevix, R.	<i>Observations on Mineralogical Systems</i>	1811	138	0 P, 0 WE		
Cleaveland, P.	<i>An Elementary Treatise on Mineralogy and Geology</i>	1816	688	6 P, 0 WE	DL = 1?	
Clinton, D.	<i>An Introductory Discourse</i>	1815	160	0 P, 0 WE		
Conybeare & Phillips	<i>Outlines of the Geology of England and Wales</i>	1822	470	3 P, 23WE	AL = 8 DL = 7	wood engravings in text, unusual for this time
Cuvier, G.	<i>Essay on the Theory of the Earth</i>	1819	305	0 P, 0 WE		
Cuvier, G.	<i>A Discourse on the Revolutions of the Surface of the Globe</i>	1831	252	10 P, 0 WE		general proxy images of fossils
Cuvier & Brongniart	<i>Description Géologique Des Environs de Paris</i>	1822	428	18 P, 0 WE	AL = 22 DL = 3	fossils & sections
Dana, J. & Dana, S.	<i>Outlines of the Mineralogy and Geology of Boston</i>	1818	108	1 P, 0 WE	DL = 1	Primitive map as the only illustration
De la Beche, H.	<i>A Selection of Geological Memoirs Contained in the Annales des Mines</i>	1824	435	11 P, 0 WE	AL = 19 DL = 4	unusual sectional views alongside map; generally good illustrations
De la Beche, H.	<i>Geological Notes</i>	1830	69	2 P, 0 WE	AL=8, DL=4	river formation plate educational
De la Beche, H.	<i>Sections and Views Illustrative of Geological Phaenomena</i>	1830	71	40 P, 0 WE	AL = 99, DL = 36	small multiples! , colored, labels, keys
De la Beche, H.	<i>A Geological Manual</i>	1831	535	0 P, 104 WE	AL = 47	many proxies
De la Beche, H.	<i>A Geological Manual, 3rd edition</i>	1833	629	0 P, 122 WE	AL = 47	added vignettes of deep time from 1831
De la Beche, H.	<i>Researches in Theoretical Geology</i>	1834	342	0 P, 46 WE	AL=39, DL=2	fewer woodcuts, but good view of earth from outer space as frontispiece, some correlation of variables
De la Beche, H.	<i>How to Observe Geology</i>	1835	312	0 P, 138 WE	AL=119, DL=1	more diagrams instead of labeled proxies, directional
De la Beche, H.	<i>Report on the Geology of Cornwall, Devon, and West Somerset</i>	1839	648	12 P, 84 WE	AL = 77 DL = 8	diagrams drawn for instruction
Deluc, J. A.	<i>An Elementary Treatise on Geology</i>	1809	413	0 P, 0 WE		
Deluc, J. A.	<i>Letters on the Physical History of the Earth</i>	1831	284	0 P, 0 WE		
Devèze de Chabriel, J.	<i>Essai géologique et minéralogique</i>	1827	104	1 P, 0 WE	DL = 1	
Eaton, A.	<i>An Index to the Geology of Northern States</i>	1818	52	1 P, 0 WE	DL = 1	Bad graphic! NO numbers or id directly labeled on graphic
Eaton, A.	<i>A Geological and Agricultural Survey</i>	1824	163	3 P, 0 WE	AL = 1 DL = 2	Hand-colored map, but no color key. Direct labels
Finch, J.	<i>Travels in the United States</i>	1833	455	0 P, 0 WE		
Girardin, J. & Lecoq, H.	<i>Elémens de Minéralogie</i>	1826	522	4 P, 0 WE		Plate 3 has a geode; plate 1 simple crystal shapes.
Greenough, G.	<i>A Critical Examination of the First Principles of Geology</i>	1819	336	1 P, 0 WE	DL = 1	wood engraving? Directly in text, simple & clean
Humboldt, A. von	<i>Fragmente einer Geologie und Klimatologie Asiens</i>	1832	272	2 P, 0 WE	DL = 2 MATH	wonderful isotherm illustration!

Author	Text	Year	# Pages	Plates/WE	Additions	Notes
Hutton, J.	<i>Theory of the Earth</i>	1788	128	2 P, 0 WE		proxy images, heavy shading
Hutton, J.	<i>Theory of the Earth, vol. I</i>	1795	620	4 P, 0 WE		proxy images, heavy shading
Hutton, J.	<i>Theory of the Earth, vol. II</i>	1795	567	2 P, 0 WE		proxy images, heavy shading
Lecoq, H.	<i>Eléments de géologie et d'hydrographie</i>	1838	516, 563	7 P, 0 WE		scene from deep time in frontispiece
Lacoste, P.	<i>Lettres minéralogiques et géologiques sur les volcans</i>	1805	440	0 P, 0 WE		
Leblond, J.	<i>Description de la Guyane</i>	1824	91	0 P, 0 WE		
Lyell, C.	<i>Principles of Geology, vol. I</i>	1830	511	1 P, 33 WE	DL, AL	proxy images with chartjunk; labeled inferred proxies
Lyell, C.	<i>Principles of Geology, vol. II</i>	1832	330	2 P, 9 WE	AL, DL	sparsely illustrated compared to vol. I, mostly fossils
Lyell, C.	<i>Principles of Geology, vol. III</i>	1833	558	5 P, 93 WE		additional wood engravings, proxies still heavy
Lyell, C.	<i>Elements of Geology</i>	1838	543	1 P, 294 WE		frontispiece of rock cycle is excellent.
Macgillivray, W.	<i>A Manual of Geology</i>	1840	258	0 P, 43 WE	DL, AL	small text
Mantell, G.	<i>The Fossils of the South Downs</i>	1822	327	42 P, 7 WE		engraved by Mrs. Mantell, AL, DL proxy wood engravings heavy
Mantell, G.	<i>Thoughts on a Pebble</i>	1836	18	1 P, 0 WE		beautifully colored grand illustration
Mantell, G.	<i>The Geology of South-east of England</i>	1833	411	5 P, 65 WE	AL = 10, DL = 1	
Mantell, G.	<i>The Wonders of Geology</i>	1838	689	5 P, 80 WE	AL, DL	Plate 5 takes advantage of the resolution of human eye, darker, heavier illustration
Maccullough, J.	<i>A Geological Classification of Rocks</i>	1821	655	0 P, 0 WE		
Mawe, J.	<i>Familiar Lessons on Mineralogy and Geology</i>	1825	110	4 P, 0 WE		Colored plate of minerals is fantastic! Someone must have spent a lot of time with these.
Mease, J.	<i>A Geological Account of the United States</i>	1807	492	6 P, 0 WE	AL = 0 DL = 0	Just sketches, no additional info on graphics
Moore, N.	<i>Ancient Mineralogy</i>	1834	191	0 P, 0 WE		
Murchison, R.	<i>The Silurian System, vol. I, II</i>	1839	767	56 P, 112 WE	AL, DL	No color keys at times; some of the colors not found in nature; beautiful map at end
Murray, J.	<i>A Comparative View of Huttonian and Neptunian Systems of Geology</i>	1802	256	0 P, 0 WE		
Omalius d'Halloy	<i>Eléments de Géologie</i>	1831	558	0 P, 0 WE		
Omalius d'Halloy	<i>Introduction à la Géologie</i>	1833	894	17 P, 0 WE		typical mineralogical sketches
Phillips, J.	<i>A Guide to Geology</i>	1835	167	0 P, 7 WE		
Phillips, J.	<i>Treatise on Geology</i>	1837- 1839	334, 308	0 P, 96 WE		regular wood engravings, some
Phillips, W.	<i>An Outline of Mineralogy and Geology</i>	1815	193	4 P, 0 WE	DL	No color key, graphic ignorance = plates not in order; mountains drawn, but no scale.
Playfair, J.	<i>Illustrations on the Huttonian</i>	1802	528	0 P, 0 WE		
Reboul, H.	<i>Géologie de la Période Quaternaire</i>	1833	222	0 P, 0 WE		
Reboul, H.	<i>Essai de Géologie Descriptive et Historique</i>	1835	276	0 P, 1 WE	AL = 3	
Scrope, G. P.	<i>Considerations on Volcanoes</i>	1825	270	3 P, 23 WE	AL = 2	good parallel depiction of mountain ranges & volcanoes
Scrope, G. P.	<i>Memoir on the geology of central France</i>	1827	172	1 P, 0 WE	DL = 1	
Smith, R.	<i>Geological &amp; Phisiological Disquisition</i>	1812	24	0 P, 0 WE		
Smith, W.	<i>Synoptical Table of Organized</i>	1817	118	0 P, 0 WE		
Sutcliffe, J.	<i>A Short Introduction to the Study of Geology</i>	1817 - 1819	103	0 P, 0 WE		
Thomson, T.	<i>Outlines of Mineralogy, Geology, and Mineral Analysis</i>	1836	566	0 P, 6 WE		glassware proxies
Ure, A.	<i>A New System of Geology</i>	1829	621	7 P, 51 WE		Most without titles
Von Buch, L.	<i>Ueber einen vulcanischen Ausbruch auf der Insel</i>	1820	14	0 P, 0 WE		

## Appendix N: Statistical Analysis of Geological Illustrations

Author	Text	Year	Number of Pages	Plates/WE	Graphic Density
Aubuisson de Voisins	<i>Traité de géognosie</i>	1819	v1=496 v2=665	1P/0WE, 1P/0 WE	0.0017
Aubuisson de Voisins	<i>Traité de géognosie, Nouvelle edition</i>	1828 - 1835	v1=524 v2=629 v3=671	1P/0WE, 8P/0 WE 9P/0WE	0.0099
Bakewell, R.	<i>An Introduction to Geology</i>	1813	362	5 P, 0 WE	0.014
Bakewell, R.	<i>An Introduction to Geology 3rd edition</i>	1829	400	6 P, 2 WE	0.02
Bakewell, R.	<i>An Introduction to Geology 3rd ed. From 5th London ed.</i>	1839	596	8 P, 32 WE	0.067
Boase, H.	<i>A Treatise on Primary Geology</i>	1834	399	0 P, 24 WE	0.06
Boubée, N.	<i>Géologie Élémentaire</i>	1833	236	1 P, 0 WE	0.0042
Breislak, S.	<i>Introduzione alla geologia</i>	1811	367, 490	0 P, 0 WE	0
Breislak, S.	<i>Institutions géologiques. Traité sur la structure extérieure du globe</i>	1818 - 1822		56 P in atlas	N/A
Buckland, W.	<i>Reliquiæ Diluvianæ</i>	1824	303	27 P, 0 WE	0.089
Chenevix, R.	<i>Observations on Mineralogical Systems</i>	1811	138	0 P, 0 WE	0
Cleaveland, P.	<i>An Elementary Treatise on Mineralogy and Geology</i>	1816	688	6 P, 0 WE	0.0087
Clinton, D.	<i>An Introductory Discourse</i>	1815	160	0 P, 0 WE	0
Conybeare & Phillips	<i>Outlines of the Geology of England and Wales</i>	1822	470	3 P, 23WE	0.055
Cuvier, G.	<i>Essay on the Theory of the Earth</i>	1819	305	0 P, 0 WE	0
Cuvier, G.	<i>A Discourse on the Revolutions of the Surface of the Globe</i>	1831	252	10 P, 0 WE	0.04
Cuvier & Brongniart	<i>Description Géologique Des Environs de Paris</i>	1822	428	18 P, 0 WE	0.042
Dana, J. & Dana, S.	<i>Outlines of the Mineralogy and Geology of Boston</i>	1818	108	1 P, 0 WE	0.0093
De la Beche, H.	<i>A Selection of Geological Memoirs Contained in the Annales des Mines</i>	1824	435	11 P, 0 WE	0.025
De la Beche, H.	<i>Geological Notes</i>	1830	69	2 P, 0 WE	0.029
De la Beche, H.	<i>Sections and Views Illustrative of Geological Phaenomena</i>	1830	71	40 P, 0 WE	0.57
De la Beche, H.	<i>A Geological Manual</i>	1831	535	0 P, 104 WE	0.19
De la Beche, H.	<i>A Geological Manual, 3rd edition</i>	1833	629	0 P, 122 WE	0.19
De la Beche, H.	<i>Researches in Theoretical Geology</i>	1834	342	0 P, 46 WE	0.13
De la Beche, H.	<i>How to Observe Geology</i>	1835	312	0 P, 138 WE	0.44



Author	Text	Year	Number of Pages	Plates/WE	Graphic Density
De la Beche, H.	<i>Report on the Geology of Cornwall, Devon, and West Somerset</i>	1839	648	12 P, 84 WE	0.15
Deluc, J. A.	<i>An Elementary Treatise on Geology</i>	1809	413	0 P, 0 WE	0
Deluc, J. A.	<i>Letters on the Physical History of the Earth</i>	1831	284	0 P, 0 WE	0
Devèze de Chabriol, J.	<i>Essai géologique et minéralogique</i>	1827	104	1 P, 0 WE	0.0096
Eaton, A.	<i>An Index to the Geology of Northern States</i>	1818	52	1 P, 0 WE	0.019
Eaton, A.	<i>A Geological and Agricultural Survey</i>	1824	163	3 P, 0 WE	0.018
Finch, J.	<i>Travels in the United States</i>	1833	455	0 P, 0 WE	0
Girardin, J. & Lecoq, H.	<i>Éléments de Minéralogie</i>	1826	522	4 P, 0 WE	0.0077
Greenough, G.	<i>A Critical Examination of the First Principles of Geology</i>	1819	336	1 P, 0 WE	0.003
Humboldt, A. von	<i>Fragmente einer Geologie und Klimatologie Asiens</i>	1832	272	2 P, 0 WE	0.0074
Hutton, J.	<i>Theory of the Earth</i>	1788	128	2 P, 0 WE	0.016
Hutton, J.	<i>Theory of the Earth, vol. I</i>	1795	620	4 P, 0 WE	0.0065
Hutton, J.	<i>Theory of the Earth, vol. II</i>	1795	567	2 P, 0 WE	0.0035
Lecoq, H.	<i>Éléments de géologie et d'hydrographie</i>	1838	516, 563	7 P, 0 WE	0.0065
Lacoste, P.	<i>Lettres minéralogiques et géologiques sur les volcans</i>	1805	440	0 P, 0 WE	0
Leblond, J.	<i>Description de la Guyane</i>	1824	91	0 P, 0 WE	0
Lyell, C.	<i>Principles of Geology, vol. I</i>	1830	511	1 P, 33 WE	0.067
Lyell, C.	<i>Principles of Geology, vol. II</i>	1832	330	2 P, 9 WE	0.033
Lyell, C.	<i>Principles of Geology, vol. III</i>	1833	558	5 P, 93 WE	0.18
Lyell, C.	<i>Elements of Geology</i>	1838	543	1 P, 294 WE	0.54
Macgillivray, W.	<i>A Manual of Geology</i>	1840	258	0 P, 43 WE	0.17
Mantell, G.	<i>The Fossils of the South Downs</i>	1822	327	42 P, 7 WE	0.15
Mantell, G.	<i>Thoughts on a Pebble</i>	1836	18	1 P, 0 WE	0.056
Mantell, G.	<i>The Geology of South-east of England</i>	1833	411	5 P, 65 WE	0.17
Mantell, G.	<i>The Wonders of Geology</i>	1838	689	5 P, 80 WE	0.12
Maccullouch, J.	<i>A Geological Classification of Rocks</i>	1821	655	0 P, 0 WE	0
Mawe, J.	<i>Familiar Lessons on Mineralogy and Geology</i>	1825	110	4 P, 0 WE	0.036
Mease, J.	<i>A Geological Account of the United States</i>	1807	492	6 P, 0 WE	0.012
Moore, N.	<i>Ancient Mineralogy</i>	1834	191	0 P, 0 WE	0
Murchison, R.	<i>The Silurian System, vol. I &amp; II</i>	1839	767	56 P, 112 WE	0.22

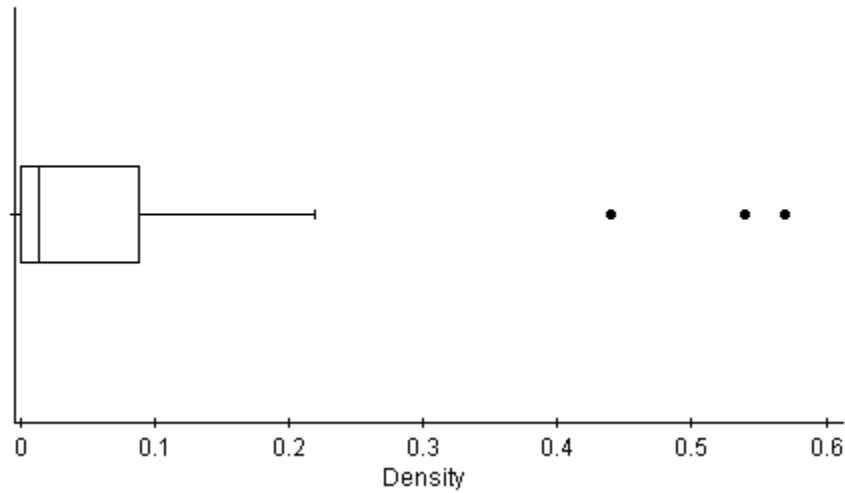
Author	Text	Year	Number of Pages	Plates/WE	Graphic Density
Murray, J.	<i>A Comparative View of Huttonian and Neptunian Systems of Geology</i>	1802	256	0 P, 0 WE	0
Omalius d'Halloy	<i>Éléments de Géologie</i>	1831	558	0 P, 0 WE	0
Omalius d'Halloy	<i>Introduction à la Géologie</i>	1833	894	17 P, 0 WE	0.019
Phillips, J.	<i>A Guide to Geology</i>	1835	167	0 P, 7 WE	0.042
Phillips, J.	<i>Treatise on Geology</i>	1837- 1839	334, 308	0 P, 96 WE	0.15
Phillips, W.	<i>An Outline of Mineralogy and Geology</i>	1815	193	4 P, 0 WE	0.17
Playfair, J.	<i>Illustrations on the Huttonian</i>	1802	528	0 P, 0 WE	0
Reboul, H.	<i>Géologie de la Période Quaternaire</i>	1833	222	0 P, 0 WE	0
Reboul, H.	<i>Essai de Géologie Descriptive et Historique</i>	1835	276	0 P, 1 WE	0.0036
Scrope, G. P.	<i>Considerations on Volcanoes</i>	1825	270	3 P, 23 WE	0.096
Scrope, G. P.	<i>Memoir on the geology of central France</i>	1827	172	1 P, 0 WE	0.0058
Smith, R.	<i>Geological &amp; Physiological Disquisition</i>	1812	24	0 P, 0 WE	0
Smith, W.	<i>Synoptical Table of Organized</i>	1817	118	0 P, 0 WE	0
Sutcliffe, J.	<i>A Short Introduction to the Study of Geology</i>	1817 - 1819	103	0 P, 0 WE	0
Thomson, T.	<i>Outlines of Mineralogy, Geology, and Mineral Analysis</i>	1836	566	0 P, 6 WE	0.011
Ure, A.	<i>A New System of Geology</i>	1829	621	7 P, 51 WE	0.093
Von Buch, L.	<i>Ueber einen vulcanishchen Ausbruch auf der Insel</i>	1820	14	0 P, 0 WE	0

Summary Statistics and Box Plots

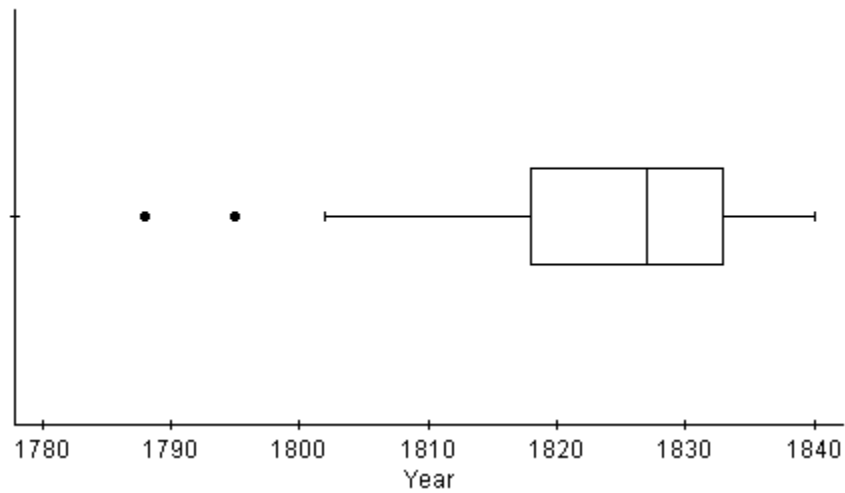
Summary Statistics for Graphic Density and Publication Year:

Column	n	Mean	Variance	Std. Dev.	Std. Err.	Median	Range	Min	Max	Q1	Q3
Year	71	1824.4789	137.76741	11.737436	1.3929774	1827	52	1788	1840	1818	1833
Density	71	0.06462535	0.012978333	0.113922484	0.013520112	0.014	0.57	0	0.57	0	0.089

Box Plot for Graphic Density:



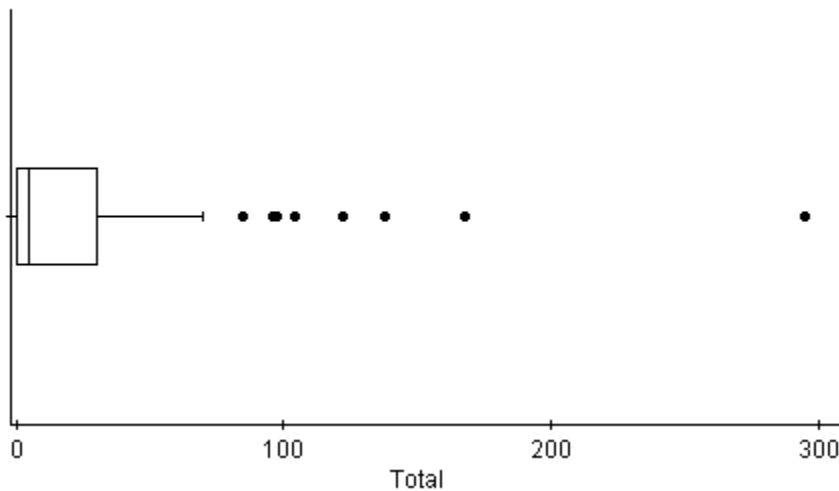
Box Plot for Publication Year:



### Summary Statistics for Total Included Illustrations and Publication Year:

Column	n	Mean	Variance	Std. Dev.	Std. Err.	Median	Range	Min	Max	Q1	Q3
Year	72	1824.3889	136.41002	11.67947	1.3764387	1827	52	1788	1840	1818	1833
Total	72	26.777779	2402.2598	49.01285	5.7762203	4.5	295	0	295	0	30.5

### Box Plot for Total Included Illustrations:



## Hypothesis Testing with a Correlation Coefficient

### Correlation of Graphic Density and Publication Year

Correlation = 0.37

Coefficient of Determination = 0.14

Test at  $\alpha = 0.01$ , two-tailed test

Null Hypothesis  $H_0 = \rho = 0$

There is no relationship between publication year of geology texts and graphic density.

Alternative Hypothesis  $H_a = \rho \neq 0$

A relationship exists between publication year of geology texts and graphic density.

$n = 71$

$df = 69$

Assumptions:

Randomly selected sample

Normal population distributions

Homoscedasticity

$$t_{ts} = r [(n-2)/(1-r^2)]^{1/2}$$

$$t_{ts} = 3.31; 3.31 > 2.576$$

Based on the evidence of the sample, the null hypothesis that stated that publication year of geology texts was not related to graphic density is rejected. The alternative hypothesis that stated that there is a relationship between publication year of geology texts and graphic density is accepted. The decision to reject the null hypothesis is done at the 99% confidence level.

### **Correlation of Total Number of Illustrations and Publication Year:**

Correlation = 0.42

Coefficient of Determination = 0.18

Test at  $\alpha = 0.01$ , two-tailed test

Null Hypothesis  $H_o = \rho = 0$

There is no relationship between publication year of geology texts and total number of illustrations.

Alternative Hypothesis  $H_a = \rho \neq 0$

A relationship exists between publication year of geology texts and total number of illustrations.

$n = 72$

$df = 70$

Assumptions:

Randomly selected sample

Normal population distributions

Homoscedasticity

$$t_{ts} = r [(n-2)/(1-r^2)]^{1/2}$$

$$t_{ts} = 3.88; 3.88 > 2.576$$

Based on the evidence of the sample, the null hypothesis that stated that publication year of geology texts was not related to total number of illustrations is rejected. The alternative hypothesis that stated that there is a relationship between publication year of geology texts and total number of illustrations is accepted. The decision to reject the null hypothesis is done at the 99% confidence level.

## Appendix O: Interactive Historical Vignette

### Mary Anning: She's More Than "Seller of Sea Shells at the Seashore"

© 2002, R.C. Godley & J.H. Wandersee

Note: Permission is granted to science teachers to reproduce this vignette, and all the other associated items found on our NABT 2002 hand-out CD-ROM, in their own classrooms, as long as credit is given. RG/JW

Yes, that famous nursery rhyme is about her! Mary Anning is now gaining in popularity. You'd be amazed by the number of new books recently written about her life and work. However, most students have never heard of Anning, and her contributions to the field of paleontology. That's the scientific study of life existing in prehistoric times, as revealed by the fossils of plants, animals, and other organisms.

Mary Anning lived in a seaside town called Lyme Regis, England in the early 1800s. She learned the art and science of collecting fossils from her father, Richard Anning. He collected fossils, cut and polished them, and sold them to the tourists who visited the area. Upon his death, Mary, her mother, and her brother, Joseph, continued the fossil business. It was Mary, however, who excelled at finding fossils in the crumbling cliffs and recovering them.

Soon she became an expert on those fossils and people asked her questions about them. She was in contact with the leading scientists of the day, and provided many specimens to the major museums of the country. Her visibility in the sciences was quite unusual in her time, since, at that time, women and those of low social standing were barred from participation in scientific societies. Mary's correspondence indicates she succeeded in spite of her gender, social status and lack of education.

She had a friend named Henry De la Beche, a prominent geologist of the 19<sup>th</sup> century. He moved to Lyme Regis as a boy, and it is suspected that the Anning family

introduced him to the fossils of the area. De la Beche eventually made geology his life and career. He became the first Director General of the British Geological Survey, and he later founded the Museum of Practical Geology and the School of Mines. De la Beche maintained contact with Mary throughout her life: He even drew a scene of ancient life that was lithographed and sold to raise money for Anning when her fortunes deteriorated.

The following vignette can be adapted for use in the biology or earth science classroom at any grade level to introduce students to Anning and De la Beche, the history of paleontology, and the nature of science. The first part of this vignette describes a paleontological discovery, and it is designed promote thinking and initiate questions from the students.

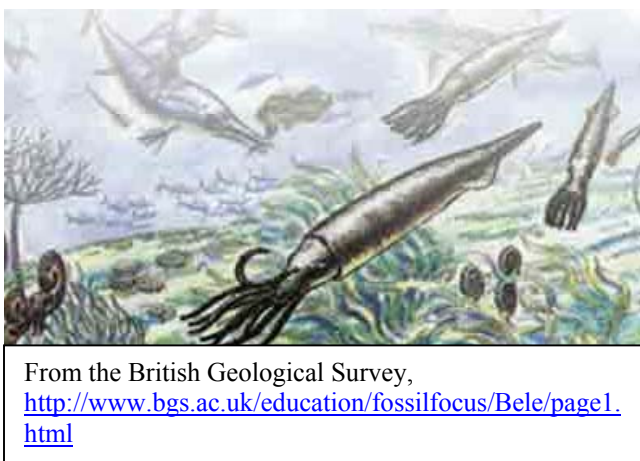
### Mary Anning: Digging Deeper

When we think back to the 19<sup>th</sup> century – the 1800s – what names in science do we remember? (This is a good opportunity to determine if students correctly place historical figures in the appropriate period. Pasteur, Watt, and Edison are acceptable answers, while Benjamin Franklin, Galileo, and Einstein are not.) What about women in science? Do we know of any women who made scientific contributions in the 1800s? (Chances are, most students have not.)

In the 1800s, most women were barred from actively participating in the scientific community because of their gender. However, there were a few women who did manage to contribute to the sciences in spite of the barriers that surrounded them. Has anyone heard of Mary Anning? (Check for student response.) You’ve probably been exposed to Mary Anning even if you don’t remember her. Do you remember learning, “She sells sea shells by the seashore?” (Check for student response.) Well, that tongue twister refers to

Mary Anning! Mary Anning collected fossils from the cliffs near her home in Lyme Regis, England, and sold them to tourists, scientists, and museums. While some people might say that Mary Anning was only a collector, others argue that Anning was the first female paleontologist – or studier of fossils – since as a woman of low social status, it would have been difficult for her to officially publish and participate in the scientific community of her time.

In 1826, Mary Anning made a discovery about one of the fossils she collected.



Has anyone heard of a belemnite (běl'əm-nīte')? (Check for student response.) Belemnites used to be called “thunder stones,” but the fossil is the remains of the interior part of a squid-like animal. At the moment we

meet Mary Anning, she is talking with her friend, the famous geologist Henry De la Beche, about her most recent discovery.

*Anning:* Henry, last week I decided to cut one of the belemnites in half, just the way Papa taught me how to cut the ammonites in half to show their internal structure. No one had ever done that with a belemnite before, and I was curious to see what might be inside of it.

*De la Beche:* Good idea, Mary! And what did you find?

*Anning:* Actually, there was something very interesting inside: a tiny chamber, filled with what appeared to be a dried-up substance. I remembered that the modern sea-hares emit purple ink when they are scared, so I thought, just perhaps, the dried-up substance might be old ink!

STOP. Ask students to analyze this situation. Was this discovery important? Does the discovery help to relate ancient animals with modern animals? Did Mary Anning *know* what the dried substance was? How did she *infer* what the dried substance was? How



can Mary Anning *use* or *apply* her discovery? Students should be encouraged to discuss how Mary Anning approached her discovery, and the possible applications of her findings.

*De la Beche:* Hmmm. That's interesting. Maybe we could actually make use of that old ink!

*Anning:* That's what I wondered! So my friend, Elizabeth Philpot, scraped out some of the dried substance and added a little water to it to make it into a paste. Then she and I drew a picture of an ichthyosaur with it.

*De la Beche:* Mary, that is great! We can use this fossilized ink to draw pictures of the very animals – ichthyosaurs and plesiosaurs – that were alive when it was! I would imagine that the visitors to Lyme Regis might be interested in buying these pictures as souvenirs, just as they buy some of the ammonites and belemnites that you collect.

*Anning:* Now that is an idea! Henry, you are a very talented artist. Will you draw some pictures with the fossilized ink?

Henry De la Beche did use the fossil ink to draw pictures of animals that were alive at the time the belemnites were. Soon local artists of Lyme Regis also began painting with the ancient ink, and the tourist industry in Lyme Regis increased. Mary Anning was then able to sell many belemnites to the Reverend William Buckland, professor of geology at Oxford University. He studied them, and verified what Mary Anning and Elizabeth Philpot believed: The belemnites were able to hide from predators by expelling the ink (Goodhue, unpublished manuscript, 2002).

FURTHER THE DISCUSSION. Relate this vignette to the nature of science and modern science through student discussion. Possible questions include, but are not limited to, the following: What characteristics of a good scientist do you see in this story? What can you infer about Mary Anning? Do scientists today approach problems in the same way? How might the situation have been handled today? What do you think about the nature of science (Is it only related to “science,” or does it extend beyond to other areas?)

Teachers should also provide students with the list of additional resources on Mary Anning. (Perhaps you might give each of them one of our bookmarks. A detailed map of England would also be helpful.) Students who have had their interest piqued will undoubtedly research the topic further.

## Appendix P: The Spelling of a Name

There exists some disagreement on the spelling of Henry T. De la Beche's name. The Norman lineage claimed by the Beche family would encourage the use of a lowercase "d," for a resultant spelling of Henry T. de la Beche. De la Beche signed his name sometimes with the lowercase "d" as well. F. J. North, who researched De la Beche extensively in the mid-20th century, also referred to him with the small "d."

However, most British geologists and historians of geology cite Henry T. De la Beche's name with a capital "D" since he was an Englishman, not a Frenchman. Also, De la Beche often signed his name with a capital "D." Martin Rudwick (personal communication, January 20, 2003) noted that in the United Kingdom, De la Beche's name is indexed under "D," not "B." It is European convention to index such names under the substantive part of the name if they are "Continental." An exception to this system was found in the Geological Society of London's library card catalog, where many of the De la Beche publications *are* indexed under "B."

The decision was made to use the capital "D" in this dissertation based on several factors, including a recommendation by Martin Rudwick (personal communication, January 20, 2003), and the widespread use of the capital "D" among geologists and historians of geology today. The National Museum of Wales, in which the De la Beche archive is housed, and the British Geological Survey, of which De la Beche was first director, use the capital "D." De la Beche also endorsed the capital "D," although there was variation in his signature: He also signed his name as "de la Beche," and, on at least one occasion, as "De la Beeche."

## Vita

Renee M. Clary received her Bachelor of Science degree in chemistry in May, 1983 from the University of Louisiana at Lafayette. At graduation, she was named the Outstanding Graduate of the College of Science.

In the fall of 1995, she returned to the University of Louisiana at Lafayette to pursue a Master's Degree in education with joint certification. However, after one semester in the College of Education, geology piqued her interest, and she decided to pursue a Master's Degree in geology. Renee was awarded the Board of Regents Fellowship to study geology for two years. She was graduated in December, 1997 with a Master of Science degree in geology. At the graduation ceremony, she was named the Outstanding Graduate Student of the University and was presented with the Richard G. Neiheisel Phi Beta Kappa Endowed Award. Her master's thesis was entitled, "A Stratigraphic Interpretation of an Arctic Core, Based on Benthonic Foraminiferal and Dropstone Analyses."

In the spring of 1998, Renee returned to the College of Education to finish her Master of Education degree in curriculum and instruction at the University of Louisiana at Lafayette. She fulfilled the requirements for the degree in December, 1998.

She entered the Ph.D. program in curriculum and instruction at Louisiana State University in the summer, 2001. Upon completion of a course entitled The Graphic Representation of Scientific Knowledge taught by Dr. James Wandersee, she became interested in the early visual representations of knowledge in geology. This dissertation is the culmination of that early interest and research. Thus far, two conference presentations have resulted from this investigation:

- Godley, R. C., & Wandersee, J. H. (2003, March). *Can scientific caricatures stimulate and enhance geoscience learning? Lessons from the history of geology*. Paper presented at the meeting of the National Association for Research in Science Teaching, Philadelphia, PA.
- Godley, R. C., & Wandersee, J. H. (2002, November). *Introduce them to Mary Anning: She's more than "seller of sea shells at the seashore."* Paper presented at the meeting of the National Association of Biology Teachers, St. Louis, MO.

Renee is a member of the American Educational Research Association, the Geological Society of America, the History of Geology Group (London Geological Society), Kappa Delta Pi, Lafayette Geological Society, Louisiana Science Teachers Association, Louisiana State University's 15<sup>o</sup> Laboratory research group, the National Association of Biology Teachers, the National Association of Geoscience Teachers, the National Association for Research in Science Teaching, the National Earth Science Teachers Association, the National Science Teachers Association, and the Society for College Science Teachers.

Renee has worked in research and development for a major chemical corporation, and has been the chief laboratory specialist in the investigation of asbestos in school insulation materials. She has also been employed with the Microelectronics Research Laboratory, and has taught chemistry and calculus at a local college preparatory school. Currently, she is employed in the Department of Geology at the University of Louisiana at Lafayette, and also teaches geology courses at South Louisiana Community College.